International Conference on Advanced Technology & Sciences

3rd International Conference, ICAT’16
Konya, Turkey, September 01-03, 2016

Proceedings

Editors
Ismail SARITAS
Omer Faruk BAY
Kemal TUTUNCU

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PREFACE

International Conference on Advanced Technology & Sciences (ICAT'16) has been organized in Konya, Turkey on 01-03 September, 2016.

The aim of International Conference on Advanced Technology & Sciences is to provide a platform for researchers and academics as well as practicing professionals from all over the world, to present their research and professional development activities in Computer, Electric and Electronics, Energy and Mechatronics. This conference provides opportunities for the different areas delegates to exchange new ideas and application experiences face to face, to establish business or research relations and to find global partners for future collaboration. We hope that the conference results constituted significant contribution to the knowledge in these up to date scientific fields.

All full paper submissions have been double blind and peer reviewed and evaluated based on originality, technical and/or research content/depth, correctness, relevance to conference, contributions, and readability. Selected papers presented in the conference that match with the topics of the journals will be published in the following journals:

- International Journal of Intelligent Systems and Applications in Engineering (IJISAE)
- International Journal of Applied Mathematics, Electronics and Computers (IJAMEC)
- International Journal of Energy Applications and technology (IJEAT)
- International Journal of Automotive Engineering and Technologies (IJAET)

At this conference, there are 700 paper submissions from 107 different universities. Each paper proposal was evaluated by two reviewers and 416 of these were accepted for presentation. And finally, 366 papers will be presented at our conference.

We are sure that, ICAT will be the flagship conference for researchers, students, and professionals in the areas of Electrical and Computer Engineering, Biomedical Engineering, Energy and Manufacturing Engineering and their applications from Turkey and around the world to disseminate their research advancements and discoveries, to network and exchange ideas in order to strengthen existing partnerships and foster new collaborations.

In particular we would like to thank Prof. Dr. Mustafa SAHIN, Rector of Selcuk University; Advanced Technology and Sciences, Academic Publisher; International Journal of Intelligent Systems and Applications in Engineering (IJISAE); International Journal of Applied Mathematics, Electronics and Computers (IJAMEC); Konya Metropolitan Municipality, Province of Konya Culture and Tourism Directorate, Konya Chamber of Industry, Konya Chamber of Commerce, Firdevs Patent and AYBIL Organization. They have made a crucial contribution towards the success of this conference. Our thanks also go to the colleagues in our conference office.

Looking forward to see you in next ICAT.

Ismail SARITAS - Omer Faruk BAY
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An Efficient Resource Management in Cloud Computing

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Abstract— A cloud computing is gaining more recognition to the public, request for services to a given task within the virtual environment of the cloud also increases. This paper proposed a max-min algorithm like technique with the aim of developing a new framework that tends to balance the load that may be experienced due to the high demand of resources by a set of task within the virtual environment of the cloud computing ecosystem.

Keywords— Load balancing, Max-min algorithm, Makespan, Min-min algorithm, Task Scheduling, Resource Allocation.

I. INTRODUCTION

The fast development in the area of computing gives users of computer system the opportunity to have access as well as exploit the vast resources that are contained within the system. Cloud Computing is seen as a new technology that adopt the aspect of distributed computing and internet. The concept of cloud is to allow a client or a customer to have access to computing resources through the use of web services in a more efficient manner. Resources in the field of information and communication technology are more or less the fundamental elements that include some part of computer systems, computer networks, software application and so on. Managing these resources involve controlling and limiting access to the pool of resources that are been shared. This brings the concept of an agreement between the resource services providers and the clients otherwise known as Service Level Agreement (SLA). The idea behind the SLA is to restrict access to a given resources.

Cloud resource management may involve some policies such as admission control, Quality of Service (QoS) which involves specification from SLA. Other policy which is the main topic regarding this research is Load Balancing which involves balancing the work load evenly among the cloud servers. The cloud services are provided to customers through the use of virtual hardware, the services provided to the client such as IaaS, SaaS, and PaaS as shown in Fig. 1 can be scale up or down depending on the client’s level of usage and the SLA adopted.

Revolutionary increase of users and demand for various services parallel with the need for efficient resources usage reveal that load balancing should be done correctly and efficiently. The aimed of which is to optimize resources utilization, maximize throughput, minimize response time, and avoiding overload. Many load balancing algorithms have been designed so far, and the need for much more efficient algorithm that, with other things, also fairly allocate the loads across the system is high. Moreover, each developed algorithm has its own draw back and mostly performs better in one application than in others [12].

Load balancing, the absence of which negatively rises some issues (in performance, availability), is one of the primary challenges in cloud computing [12] [14]. For improvement upon the available solutions, of which min-max relatively performs well [13], a modified and extensively improved algorithm is formed.

The other part of this paper is organized as follows: Section 2 discussed on some previous studies related to task scheduling algorithms. In Section 3 and 4 we introduce some concept with regard to the technique for task scheduling and resource allocation in cloud computing, section 4 discuss on the issues pertaining load balancing, mathematical formulation, and the proposed algorithm. In section 5, mathematical simulation and results are discussed, and lastly concluding remarks are given in Section 7.

II. RELATED WORK

As research in cloud environment is increasing, task scheduling needs to be more scalable to the user demands. [1][2] Uses a technique known as improved max-min algorithm and enhance max-min algorithm respectively with the aim of distributing the load among the available resources. [1] is a modification of [2] in which both uses the max-min task scheduling algorithm. This paper employs the technique in [1] to propose another algorithm that will help in balancing load across the virtual resources and to allow for scalability when handing task with the aim of improving the performance of the system. Load balancing over resources in the cloud environment is used to achieve minimum load when using resources, different methods are use to achieved such balance as stated in [7, 8, and 9]. Based on these methods, we take interest in max-min algorithm and shows how load can be balanced across different resources in the cloud environment.

III. CLOUD COMPUTING AND TASK SCHEDULING

As the aspect of parallel and distributed computing involves Cloud computing which is a collection of computers that are interconnected and virtualized as one computing
resources, cloud client gets access to the resources through the SLA [11].

As mentioned previously, cloud computing offers software, platform, and infrastructure as a service respectively. The software as a service includes providing software such as Mail (e.g., Gmail, Yahoo mail), social network sites, Google drive, and so on, to the customers or clients. The infrastructure as a service deals with VM, storage, network, load balancer and so on as a service to the client and lastly the platform as a service deals with database like SQL, oracle, web services, runtime (e.g., Java) and so on as a service to the client. The clients get access to these services through various devices as shown in the figure below [3] [4].

Resource allocation in cloud computing is all about assigning available resources to a cloud application. Dynamic resource management is seen as a very active research area in the field of cloud computing. The cloud computing resources costs vary depending upon the type of configuration for using such resources. Therefore, an efficient use of these resources is considered as a prime interest for both the customer/client and the cloud provider. Resource allocation in cloud computing takes place in two levels [5]: firstly load is balanced within the physical machine whenever an application is uploaded and secondly, request are assigned to a specific application if there are multiple requests for the resource.

Resource allocation exhibits some benefits irrespective of the organization size or business market. It also has some limitations below are some set of advantages and limitations of resource allocation [6]; among the advantages is that users share their resources whenever there is a scarcity of resources. The limitation may arise in the aspect of security, which is a major challenge and another setback is that migration issues may arise whenever a client decides to switch service providers.

IV. LOAD BALANCING AND TASK SCHEDULING ALGORITHM

Load balancing is a technique used to distribute processing load (i.e., large processing load) to smaller processing nodes (i.e., resources) to enhance the overall performance within the system in a distributed environment as shown in fig. 2 above. The idea of load balancing is to avoid loading up a resource during task scheduling so that all the resources will be allocated with a task evenly across a given virtual environment. Various load balancing algorithms exist as stated in [7] with the aim of distributing the task’s load across resources. Some of these algorithms include:

- **Min-Min Algorithm**

  This algorithm has all the relevant information needed in advance. The algorithm uses some parameters to obtain the information it needs. Some of these parameters are: ETC (Expected Time Compute), MET (Minimum Execution Time), MTC (Minimum Completion Time) etc. The Min-Min algorithm selects a task with minimum completion time and maps it with a node with a minimum completion time [8].

- **Max-Min Algorithm**

  Max-min algorithm chooses large task to be executed first before executing small once [10]. This algorithm works almost the same way as the Min-Min algorithm except in Max-Min the task with maximum value is selected from the set of execution time of tasks and maps it to a node with
minimum completion time. The ready time of the node is updated by adding the execution time of the task \([7, 8]\).

As the cloud users send task to the cloud environment with different requirement to the cloud service providers. The requirement can be tasks with different set of data size and processing power, the task scheduler will then match the tasks with available resources (virtual resources) that are available. Some mathematical relations are given in \([9]\) to analyze resources scheduling in cloud computing which are employed and used in this paper are given below.

The set of VMs \(V\) with their respective processing power is given as:

\[
V = \{v_j(c_j) | j = 1, 2, ..., k\} \tag{1}
\]

The set of tasks is also given as

\[
T = \{t_i(a_i, b_i) | i = 1, 2, ..., y\} \tag{2}
\]

Where

\[
c_j = \text{processing speed (MIPS)}
\]

\[
t_i = \text{given task i}
\]

\[
a_i = \text{Data file size of a given task (Mb)}
\]

\[
b_i = \text{Processing power (MI) of a task t_i}
\]

With above equations (1) and (2) the expected execution time (EET) for a given task by a virtual resource can be obtained as:

\[
EET = \frac{\text{Size of task (MI)}}{\text{Computing Power of resource (MIP)}} \tag{3}
\]

Now with equation (3) above, another metric can be obtained, which is the completion time (CT) of task \(t_i\) by a given resource.

\[
CT_{(i,j)} = EET_{(i,j)} + r_i \tag{4}
\]

Where \(r_i\) indicate the starting time of the execution of task \(t_i\).

Using (4), another important metric can be obtained, which is called the makespan, define as a measure of the throughput of the heterogeneous computing system \([7]\).

\[
\text{makespan} = \max_{(w, j)}(CT_{i,j}) \tag{5}
\]

This paper employs a known scheduling algorithm called an improved max-min algorithm from \([1]\) and then based on this algorithm we propose another algorithm that will help in balancing load across the VMs’ resources to improve the performance of the system.

- Improved Max-Min Algorithm

The Max-min algorithm allocated task \(t_i\) to resource \(v_j\) such that large tasks have higher priority. For instance for a given large task, the max-min algorithm execute smaller task concurrently while running large tasks. Therefore, the largest task determines the total makespan for other resources. The improved max-min algorithm is given below \([2]\).

\[
\text{For all submitted tasks in Meta-task; } t_i \\
\quad \text{for all resources; } v_j \\
\quad C_{ij} = E_{ij} + t_i \\
\quad \text{Find task } t_i \text{ costs maximum execution time} \\
\quad \text{Assign task } t_i \text{ to resource } v_j \text{ which gives minimum completion time} \\
\quad \text{Remove task } t_i \text{ from Meta-tasks set.} \\
\quad \text{Update } t_i \text{ for selected } v_j. \\
\quad \text{Update } c_{ij} \text{ for all } j. \\
\quad \text{While Meta-task not Empty} \\
\quad \text{Find task } t_i \text{ costs maximum execution time.} \\
\quad \text{Assign task } t_i \text{ to resource } v_j \text{ which gives minimum completion time} \\
\quad \text{Remove Task } t_i \text{ from Meta-tasks set.} \\
\quad \text{Update } t_i \text{ for selected } v_j. \\
\quad \text{Update } c_{ij} \text{ for all } j.
\]

- Proposed Algorithm

The improved max-min algorithm is reliable and proved to be efficient in scheduling the set of tasks to the available resources. However to make effective and sufficient use of resource a proposed algorithm was introduced which is based on the improved max-min algorithm but small changes are made to make sure that all resources are used sufficiently and to minimize the use of these resources if few once can perform the task. The proposed algorithm is shown in the pseudo code below:

\[
\text{For all submitted tasks in Meta-task; } T_i \\
\quad \text{for all resources; } R_j \\
\quad C_{ij} = E_{ij} + t_i \\
\quad \text{Find task } T_i \text{ costs maximum execution time} \\
\quad \text{Assign task } T_i \text{ to its corresponding resources } R_j \\
\quad \text{Remove task } T_i \text{ from Meta-tasks set.} \\
\quad \text{Update } r_j \text{ for selected } R_j. \\
\quad \text{Update } C_{ij} \text{ for all } j. \\
\quad \text{Pivot= } 2\text{pivot}\text{- } t_i \\
\quad \text{For all updated task in Meta-task; } T_i \\
\quad \text{for all updated resources; } R_j \\
\quad \text{Find task } T_i \text{ costs maximum execution time} \\
\quad \text{Assign task } T_i \text{ to its corresponding resource } R_j \\
\quad \text{Remove task } T_i \text{ from Meta-tasks set.} \\
\quad \text{Update } r_j \text{ for selected } R_j. \\
\quad \text{Update } C_{ij} \text{ for all } j. \\
\quad \text{2pivot= } t_i \\
\quad \text{While Meta-task not Empty} \\
\quad \text{Find task } T_i \text{ costs maximum execution time.} \\
\quad \text{If 2\text{pivot}< } 2\text{pivot then} \\
\quad \quad \text{Assign task } T_i \text{ to previous resource } R_j \text{ which gives minimum completion time} \\
\quad \quad \text{Remove Task } T_i \text{ from Meta-tasks set.} \\
\quad \quad \text{Update } r_j \text{ for Selected } R_j. \\
\quad \quad \text{Update } 2\text{pivot.} \\
\quad \quad \text{Else} \\
\quad \quad \text{Assign task } T_i \text{ to resource its corresponding resource } R_j \\
\quad \quad \text{Remove Task } T_i \text{ form Meta-tasks set.} \\
\quad \quad \text{Update } r_j \text{ for Selected } R_j. \\
\quad \quad \text{Update } C_{ij} \text{ for all } j.
\]
In the algorithm the total makespan is made to be a pivot 1 value for the first step and another pivot 2 value is assigned during the second step of the execution. Then during the next execution step the second pivot value and the completion time of the current state are summed up together. If they are greater than the first pivot value, then a new resource is allocated to that task.

By given this criteria, the resources can be used in a balanced manner and fewer resources can be used, the remaining resources will not be involved to minimize the use of such resources. The aim of the above algorithm when compared to the improved Max-Min algorithm is to make effective used of the available resource during scheduling.

The flowchart for the above pseudo code is given in the figure (Fig. 3).

![Flowchart of Proposed Algorithm](image-url)
VI. PROPOSED ALGORITHM RESULT AND ANALYSIS

Scenario: A theoretical analysis of predefined meta-task values and resources are used to carry out the scheduling process as given below. The tables underneath shows the meta-task values and the resources used.

<table>
<thead>
<tr>
<th>Task</th>
<th>Size of task (MI)</th>
<th>Data volume (Mb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>522</td>
<td>200</td>
</tr>
<tr>
<td>T2</td>
<td>1128</td>
<td>500</td>
</tr>
<tr>
<td>T3</td>
<td>430</td>
<td>300</td>
</tr>
<tr>
<td>T4</td>
<td>340</td>
<td>410</td>
</tr>
<tr>
<td>T5</td>
<td>570</td>
<td>328</td>
</tr>
</tbody>
</table>

Table 1: Tasks values

<table>
<thead>
<tr>
<th>R</th>
<th>Processing speed (MIPS)</th>
<th>Bandwidth (MbPS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>130</td>
<td>100</td>
</tr>
<tr>
<td>R2</td>
<td>266</td>
<td>120</td>
</tr>
<tr>
<td>R3</td>
<td>294</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 2: Resource processing speed and bandwidth

Given the above values, Matlab is employed to compute the expected execution time of each task and the results are tabulated and analyzed as given in Table 3 below:

<table>
<thead>
<tr>
<th>Task</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>4.015</td>
<td>1.962</td>
<td>1.776</td>
</tr>
<tr>
<td>T2</td>
<td>8.677</td>
<td>4.241</td>
<td>3.837</td>
</tr>
<tr>
<td>T3</td>
<td>3.308</td>
<td>1.617</td>
<td>1.463</td>
</tr>
<tr>
<td>T4</td>
<td>2.615</td>
<td>1.278</td>
<td>1.156</td>
</tr>
<tr>
<td>T5</td>
<td>4.389</td>
<td>2.143</td>
<td>1.938</td>
</tr>
</tbody>
</table>

Table 3: Expected execution time of task

From the above tables, T1, with the maximum execution time is selected and then is assigned to the corresponding resource R1. Fig. 4 shows how the allocation was performed based on the max-min idea, the task are allocated to all the available resources within the scheduler, the processing time is measured in seconds.

In contrast to the proposed max-min scheduling algorithm, the figure fig. 4 below shows how the allocation is performed.

Fig. 4: Chart for Resource Allocation for Max-Min Algorithm

Fig. 5: Chart for Resource Allocation for proposed Max-Min Algorithm

From the chart (fig. 4), the largest task T1 (the blue colour) has a maximum makespan of 8.031 and it’s scheduled to resource R1. The maximum makespan, is considered as the maximum throughput for other resources the summation of the remaining task i.e. T4 (red), T3(green), T1 (purple) and T5 (dark purple) are not up to the maximum throughput therefore they are assigned to the second resource R2. This makes it possible to balance different smaller tasks to run concurrently on different resources across the system and also to use the resources wisely when needed. Another important factor which is based on the on-demand characteristics of cloud computing is that, the number of resources used is also minimized and a resource can be put into use when there is a demand for that resource. Based on the results obtained, instead of assigning the load to the three resources, it’s possible to assign the task to only two resources, thereby increasing the efficiency of the system, thus we can have many task running concurrently on some resources and other resources can be put in use only when the need arise.
VII. CONCLUSIONS

In conclusion Cloud Computing is an on-demand service, therefore, efficient on-demand allocation of VM is needed. In this paper technique to handle on-demand allocation is analysed and it proved to be effective. Allocation of resources can be performed efficiently within a cloud environment by balancing the load across the various virtual machine resources, by employing an efficient technique for load balancing such as the max-min algorithm that was used in this paper.

The usage of max-min technique made it possible to handle resources in an efficient and balanced manner. Thus, for a better service to be experienced in a field of cloud computing, a proper and efficient allocation techniques need to be adopted.

REFERENCES

A Model of Automatic Block Reallocation in the Land Consolidation Projects Using Artificial Bee Colony Algorithm

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Abstract—Equitably reallocating of blocks among land owners has been one of the most important tasks in Land Consolidation studies. This task has to be fairly solved among landholdings for a land. This complicated problem is difficult to solve using linear methods. Therefore, a method is needed to solve this non-linear problem among land owners impartially. There are many applications employing optimization algorithms for solving the complicated and non-linear problems in literature. When we examine the literature, it is seen that Genetic Algorithm has been only used to overcome the block reallocation problem. Artificial Bee Colony (ABC) algorithm is one of the optimization algorithms that have been used to solve the non-linear and complicated problems in literature. Furthermore, this method has better performance when it is compared with the other optimization algorithms. In this study, we have aimed to fairly reallocate the landholding areas to blocks in a land by developing an algorithm using Artificial Bee Colony optimization method. When we develop the steps of the algorithm, we give priority to landholdings preferences and places of fixed installations. Data tables have been arranged by taking land consolidation data of DOT Village in Adiyaman, Turkey that into consideration. DOT Village land consolidation project includes 143 blocks and 225 landholders. Consequently, we have introduced the steps of an algorithm solving the block reallocation problem automatically using ABC for a sample land. Also, we have observed the applicability of the proposed method for automatic block reallocation problem in this study. This study is a preliminary study helping us to develop software providing to automatically solve complicated block reallocation problem in real time land consolidation process.

Keywords—Artificial Bee Colony Algorithm, Land Consolidation, Automatic Block Reallocation, Landholding, Optimization

I. INTRODUCTION

Land consolidation (LC) is an important component of determining the country farmland rational development utilizing and improving the sustainable use of land resources. Traditionally, LC is the most favourable land management approach for solving land fragmentation and it has been applied in many countries around the World [1]. Land consolidation aims to change land ownership by redistribution providing fewer, more compact, contiguous and larger land parcels for individual owners [2,3]. Land consolidation (LC) is a highly complex for spatial planning process because it involves many tasks, actors (landowners, rural engineers, local and regional administrations, consultants) [4]. Lands of landholdings in Turkey are jointly owned, fragmented, away from each other and in irregular geometric shapes. As a consequence of that, because of non-monolithic parcels, increasing in workforce demand, a great loss of time and uncultivated areas, agricultural landholdings can’t use modern farming methods. Therefore, agricultural productivity decreases constantly. Besides, agricultural parcels continue to be fragmented because of inheritance provisions, sale, newly opened roads and irrigation channels. This situation makes LC projects necessary on agricultural areas [5]. One of the important objectives of studies in agricultural LC is to increase agricultural cultivation and to eliminate the problems in the agricultural structure. Land reallocation is the most important stage of LC studies and a tool to rearrange proprietary rights. In reallocation of parcels and their emplacement on lands, there are some technical obligations such as farmer’s wishes, fixed installations, roads and irrigation network and the most suitable dimension, geometry, size and direction of parcels. These obligations can be easily overcame in the LC projects by using new computer technologies employing mathematical models [6].

LC projects consist of various steps. Within these steps, land reallocation is the most important and a time-consuming stage since high number of criteria are considered. Land reallocation is crucial for social peace to conduct land reallocation studies in such way to meet the demands of landowners and also the principles of equity and justice [7]. Many different solutions have been suggested for the land reallocation process. These are based on many mathematical models; model based on block priority [8–10], special-purpose interface program to perform land reallocation [11,12], a new model approach in reallocation [13], application of fuzzy logic in land reallocation [7], using the analytic hierarchy process in land consolidation [14], using the planning and decision support system in land consolidation [1], theoretical
framework and application of the land-redistribution modules [15], using genetic algorithm to land reallocation of land consolidation [16], a spatial genetic algorithm for automating land partitioning [17], a preliminary study for design of automatic block reallocation algorithm with genetic algorithm method [5], comparison of designed different land reallocation models [6].

Although Artificial Bee Colony (ABC) algorithm has been recently improved, there are lots of studies using ABC in literature. Karaboga and Basturk compared the Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Particle Swarm Inspired Evolutionary Algorithm (PS-EA) and Artificial Bee Colony Algorithm (ABC) in the optimization of some numerical functions and they reported that ABC was better [18]. Aydin et al. were modified the ABC algorithm and they developed the Incremental ABC algorithm in which population size was grown over time and local search was applied [19].

Heuristic methods like swarm intelligence have been employed in complicated problems that are difficult to solve. These methods simulate the social behaviours of animals like bird flocking or fish schooling. Artificial bee colony (ABC) and genetic algorithm (GA) are examples of the heuristic methods. Solutions of automatic block reallocation problems in land consolidation studies are difficult and this problem has been solved by traditional methods such block priority based. However, as artificial intelligent systems like the heuristic methods develop, the solution of such complicated problems is getting easier. Genetic algorithm (GA) is one of optimization algorithms. This optimization method was firstly demonstrated for solving the automatic block reallocation problem in land consolidation projects in some studies [5,20]. Moreover, it was concluded that the optimization methods was more successful than traditional one to reallocate the blocks in a land consolidation project [20]. Artificial bee colony algorithm (ABC) is an optimization algorithm which can solve non-linear and complicated problems. This method was firstly proposed in 2005 by Derviş Karaboga [18,21]. When ABC is compared with the other optimization algorithms, it is seen to produce good results for complicated problems described in literature. [22]. In this study, we propose an algorithmic model that can automatically solve the block reallocation problem in consolidation of a land using ABC. The steps of this model are described in results.

In this paper, we described the steps of an algorithm to solve the block reallocation problem among landholders for the land found in DOT village, Adıyaman-Turkey using ABC. ABC algorithm is preferred because it is swarm intelligence and said to be better than the other optimization algorithms. In Sect. 2, the proposed ABC algorithm and some materials are described; in Sect. 3 results and discussion are presented; in Sect. 4 conclusion is given.

II. MATERIALS AND METHODS
A. Block Reallocation in Land Consolidation

The problem encountered in LC projects can be defined as reallocating “n” number of cadastral parcels to “m” number of blocks. To this end, optimization studies have been conducted for land reallocation process [7]. The remaining amount after deducting the share from the total land amounts of each landholding in land consolidation area is placed in blocks, if possible, in a single piece and as parcels in proper geometrical shapes. In this location process; preferences of farmers, fixed installations and provisions of related legislation must be taken into account. As for this situation, new parcels can be placed in blocks in many different ways. Therefore, multiple options and solutions emerge in this process. The aim is to find the most appropriate solution for our goals. For this reason, block reallocation problem can be defined as an ‘optimization’ process [5].

B. Application Area

The study area, Dot Village is located in the east of Adıyaman Province (Fig. 1). It is situated 12 km along from Kahta district and 35 km along from Adıyaman city centre. Its altitude is 660 m. Settlement area is on the hill and Atatürk Dam Lake coast. Çataltepe east of the village, west Sarısu village, north Arlı and Zeytin villages, on the south west Beşaltı hamlet is located in the south Büyükbey village. Settlement area is between 38.170 East longitude and 37.450 North latitudes. Dot village LC project area is 1605.84 hectares. There are 225 landholding and 143 blocks in the LC project area. There are 352 cadastral parcels and 688 numbers of shares in the LC project area. Preference of 3 different blocks is made for each share.

C. Data Tables and Constraints

Two data has been prepared for block reallocation. The first data include areas of cadastral parcels, the first degree fields of cadastral parcels prepared according to the index map and farmer preferences. According to the data; there are 225 landholdings, 352 cadastral parcels and 688 numbers of shares in the LC project area. Total of the first degree areas in cadastral parcels is 9,528,608.84 m² in the LC project area.

The second data include block areas and the first degree block fields. According to the data; there are 143 blocks in the LC project area. Total of the first degree areas of blocks is
9,528,608.84 m² in the LC project area. Cadastral parcels and block plan of DOT village are displayed in Fig. 2 and Fig 3 respectively.

The constraints of block reallocation process are in the following:
1- The first degree areas of the parcels.
2- Three preferences for parcel shares of landholdings.
3- Fixed installations.
4- Defendant parcels and grasslands located in multiple blocks.

D. Artificial Bee Colony Algorithm

Artificial Bee Colony algorithm was firstly proposed as an optimization algorithm by Karaboga in 2005 [18,21]. Karaboga artificially simulated the intelligent behaviours of bees in a real bee colony to solve multidimensional optimization problems. There are three groups of bees which are employed, onlookers and scouts bees in the artificial bee colony model. Initially, colony is divided two parts. The first part of the colony includes the employed bees and second part consist the onlookers. In the artificial bee colony the numbers of food sources are equal to the number of employed bees in the artificial colony. The employed bee becomes the scout after the related food source is exhausted by the bees. The pseudo-code of ABC algorithm is given in the following Fig. 2 [18,21].

- INITIALIZE.
- REPEAT.
  (Step-1)Place the employed bees on the food sources in the memory;
  (Step-2)Place the onlooker bees on the food sources in the memory;
  (Step-3)Send the scouts to the search area for discovering new food sources.
- UNTIL (requirements are met).

Fig. 2 The main steps of ABC algorithm.

E. Application of Algorithm

Our model includes three external functions. These three functions generate population according to the constraints expressed in section 2.C (function 1), calculate the fitness of population (function 2) and select best population (function 3) respectively. A population in our model includes 100 rows (ensembles) and columns as the number of landholder. Each column stores block numbers in which one landholder area is located. Each landholder areas are randomly distributed to the blocks except fixed installations in each ensemble. Our model proposes to select the best ensemble in the population.

In the algorithm process, we set the initial values such that colony size (number of employed bees + number of onlooker bees) was 100; maximum cycle number in order to terminate the algorithm was 2000; number of parameters of the objective function was 225; control parameter in order to abandon the food source was 100 and number of the runs was three.

Generating of population worked as an external function in the model. This function was designed such as; areas of landholders having installations were fixed to their blocks for each ensemble in the population because the fixed installations found in the block areas couldn’t be changed. So this situation was a limitation in the block reallocation process. Areas of landholders having no fixed installations were reallocated to remaining blocks in the model. Areas of landholders having no fixed installations were fixed to first preferences and second preferences in the first and second ensembles of populations respectively. Third ensembles of population were generated such as; areas of landholders having second preferences but third preferences and having three preferences were jointly fixed to their preferred blocks in third ensembles. The rest of the ensembles of the population were composed such that the blocks were
randomly reallocated for landholders regardless of their preferences.

Fitness function worked as an external function in our model too. When one ensemble in the population was tested with the fitness function in our model, we calculated the settled areas and assessed the remaining areas information in m2 for each block. And, we calculated settlements status to the first, second and third preferences for each landholder. Lastly, arithmetic means of these outputs assessed the fitness status for each ensembles of population.

III. RESULTS AND DISCUSSION

In this study, we proposed to prepare the data tables of a land found in DOT village, Adıyaman Turkey. Moreover, a model was secondly developed to apply automatic block reallocation in the land consolidation project. This model aimed to use ABC algorithm. When we determined to use ABC for block reallocation in land consolidation projects, the previous studies in literature were examined and this algorithm was observed to be more feasible than the other optimization algorithms. As a result of the study, we developed the pseudo codes of the model and the flow chart of the algorithm applying automatic block reallocation process. The flow chart (in Fig. 4) and the general pseudo code of the study are given in the following;

Step 1. Set the initial values (Colony Size, Max Cycles, Run Time, Number of Parameters of objective function)
Step 2. Load data belonging to the all areas and blocks
Step 3. Set the global minimum (The amount of empty area in blocks must be min).
Step 4. If runtime number is achieved, finish the loop else go to next step.
Step 5. Generate the initial colony
Step 6. Divide the colony in two parts for employed and onlookers bees phases.
Step 7. Calculate the fitness of the employed colony
Step 8. If max cycle is achieved, finish the loop else go to next step.
Step 9. Change the individuals among ensembles as much as employed population size and derive the new population.
Step 10. Calculate the fitness of the new generated employed colony.
Step 11. Greedy selection between the old and new employed colony.
Step 12. Normalize the preferred colony.
Step 13. If the population size of onlookers is achieved finish this loop else go to next step.
Step 14. Change the individuals among ensembles as much as onlookers’ population size and derive the new population.
Step 15. Calculate the fitness of the new generated onlookers’ population.
Step 16. Greedy selection between the old and new onlookers population
Step 17. Go to step 13.

Step 19. Control the amount of food source in a limit rate.
(Scout phase)
Step 20. Go to step 8.

![Flow chart of the proposed algorithm](image)

IV. CONCLUSIONS

In this study, required model to apply the land reallocation using artificial bee colony algorithm in the land consolidation projects were designed. In this design, the first three steps before stage of writing codes with artificial bee colony algorithm for land reallocation were completed. Namely, data tables were prepared for a project land and reallocation conditions, constraints were identified for an example landholding and pseudo code and flow chart of block reallocation algorithm were prepared. In the future study, the codes of the block reallocation algorithm will be written according to developed these three steps.

ACKNOWLEDGMENT

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A Comparative Study of Statistical and Artificial Intelligence based Classification Algorithms on Central Nervous System Cancer Microarray Gene Expression Data

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Abstract—A variety of methods are used in order to classify cancer gene expression profiles based on microarray data. Especially, statistical methods such as Support Vector Machines (SVM), Decision Trees (DT) and Bayes are widely preferred to classify on microarray cancer data. However, the statistical methods can often be inadequate to solve problems which are based on particularly large-scale data such as microarray data. Therefore, artificial intelligence-based methods have been used to classify on microarray data lately. We are interested in classifying microarray cancer gene expression by using both artificial intelligence based methods and statistical methods. In this study, Multi-Layer Perceptron (MLP), Radial basis Function Network (RBFNetwork) and Ant Colony Optimization Algorithm (ACO) have been used including statistical methods. The performances of these classification methods have been tested with validation methods such as v-fold cross validation. To reduce dimension of DNA microarray gene expression has been used Correlation-based Feature Selection (CFS) technique. According to the results obtained from experimental study, artificial intelligence-based classification methods exhibit better results than the statistical methods.

Keywords—DNA microarray, classification, v-fold cross validation, feature selection, gene expression data

I. INTRODUCTION

Gene expression analysis of thousands of genes can be performed with a technique called microchip thanks to innovations in technology and research [1]. DNA microarray is high intensity gene array and it makes possible to examine thousands of gene expression profile [2]. Microarray technology provides abundance of knowledge on expression levels of thousands genes that has been used for diagnostic and prognostic purposes for various types of diseases. Microarray technology is an invention that allows for detection of too many genes. This technique is also used in many fields including medicine primarily [3]. The activity of genes in patient and healthy cells that get same tissues can compare through DNA microarray technology. This technique can help find genes associated with disease. For example, it can be used to identify a gene associated with a disease thanks to compare gene expression level of healthy and diseased cells [3]. The interest in working with the rapid advancement of DNA microarray technology is increasing day by day. These studies, is a comprehensive technology used in molecular biology and medicine. DNA microarray data analysis plays an important role the identification of genes associated with diseases such as cancer. It can be calculated in high probability that any individual is ill or healthy by identifying disease-related genes. Therefore, high performance classification methods are very important for microarray data.

Statistical methods such as Support Vector Machines, Decision Trees and Bayesian Network are the most frequently used methods in microarray classification. However, these methods can often be inadequate to solve problems which are based on especially large-scale data. Therefore, it is important to develop methods that can be effective to solve such problems.

In the last few decades, artificial Intelligence techniques are methods which are commonly used and preferred to solve difficult problems. That’s why, we are interested in classifying central nervous system microarray cancer gene expression by using artificial intelligence based classification methods including statistical methods in this study.

In the experimental analysis, the results of classification obtained by artificial intelligence methods are compared with the results of classification obtained by statistical methods. The rest of this paper is organized as follow: We describe the relevant methods in our comparison study part in Section 2. In Section 3, we introduced our experimental dataset called central nervous system cancer microarray gene expression dataset. We report the results of our experiments which are followed by statistical analysis and discussions in Section 4. Finally, we conclude the paper with an outlook to our future work about the control parameter optimization of classification algorithms.

II. METHODS

A classification function consists of two parts. First part is about selecting important features by using “feature selection” methods. Second part is about classifying data thanks to
classification methods. System component used in this study are described below.

A. Feature Selection

The number of features is usually very high in gene expression dataset. Therefore we need to reduce dimension on dataset to make better classification. Feature selection is very important process to make classification with high accuracy on microarray cancer datasets. We examined various feature selection methods and preferred Correlation based Feature Selection (CFS) because it made a successful choice among all features.

1) Correlation based Feature Selection (CFS): CFS is a simple filter algorithm that ranks feature subsets and discovers the merit of feature or subset of features according to a correlation based function. According to this approach, subsets which has the best attributes consist of attributes which have a high correlation with the corresponding class label and have low correlation with each other. The rest of features should be ignored. CFS feature subset evaluation function is shown as follows:

\[ G_S = \frac{k \overline{r}_{ci}}{\sqrt{k + k(k - 1) \overline{r}_{ii}}} \]  

(1)

where \( G_S \) is the heuristic merit of a feature subset \( S \) containing \( k \) features, \( \overline{r}_{ci} \) is the mean feature–class correlation, and \( \overline{r}_{ii} \), is the average feature-feature intercorrelation. This equation is, in fact, Pearson’s correlation, where all variables have been standardized [4].

B. Classification

1) Support Vector Machine (SVM): SVM is a statistical algorithm found by V. Vapnik [5] in the late 1960s. It is a method which is used particularly in classification microarray gene expression levels. SVM is a supervised classification algorithm based on statistical learning theory. SVM initially had designed for two-class classification of linear data and then was generalized to classify non-linear and multi-class data. The working principle of SVM is based on predicting the optimal decision function that can separate two classes from each other, in other words, the most appropriate way to define SVM is the hyper-plane, which can separate two classes each other [6]. An infinite number of non-optimal hyper-plane can be drawn to split the two sets from each other. However, SVM try to find optimal hyper-plane that provides the maximum margin to separate the two sets from each other. There are linear and nonlinear forms of classification based on kernel function. Radial basis kernel function is frequently used in classification applications. SVM is an important classification method because it is fast and especially perform good results on high dimensional attributes.

2) One Rule (OneR): One-R or “One Rule (a Rule)” is a simple algorithm proposed by Holt R.C [7]. This algorithm produces a rule in training data for each feature and then rule which has minimum error rate according to One-R is selected.

3) J48 Decision Tree: J48 is the Weka implementation of the C4.5 algorithm, based on the ID3 algorithm. The main idea of this method is to generate decision trees by using the information entropy. The method divides dataset by calculating the information gain of each attribute and attribute which provides the most benefit is used to make a decision [8].

4) Multi-Layer Perceptron (MLP): This model on which Rumelhart and his friends worked together is called error propagation model or the back-propagation model (backpropagation of the network) [9]. There are one or more hidden layer excluding an input and output layer in this model. Neurons in layers is associated with other layers. Information flow direction is forward and there is no feedback on the network in MLP. Therefore it is known as feed forward neural network. Data is not processed in neurons in the input layer. The number of neurons in this layer depends on the number of dimensions of the problem to be applied to the network. The number of hidden layer and neuron are randomly determined. The number of neurons in the output layer depends on the type of problem [10].

5) Radial basis Function Network (RBFNetwork): RBFNetwork was revealed in 1988 by inspiring the behavior of biological neurons [11]. Training of this model can be compared to curve fitting approach in multidimensional space [12]. It is used radial basis activation functions the transition from the input layer to the intermediate layer unlike other neural network structure in RBFNetwork and a non-linear clustering (cluster) analysis is performed. There are three layers called input, hidden and output on RBFNetwork like general ANN structure. The structure between the intermediate and output layer is also same in other types of Artificial Neural Networks, and training is performed among neurons which are intermediate and output layer.

6) Ant Colony Optimization Algorithm (ACO): ACO is a proposed algorithm inspired by the behavior of real ants in nature [13]. This algorithm was proposed by utilizing the ability to find the shortest path between nest and food source of the ants [14]. The use of this algorithm for solution of classification problems has been just used and Ant-Miner has been proposed by Parpinelli and his friends [15] to classify data recently. After that, Ant-Miner was developed by Liu and his friends [16] by the same logic, but different heuristic and pheromone update strategy. cAnt-Miner algorithm was also developed for data which has continuous values. High-level pseudocode of cAnt-Miner algorithm is shown Figure 1. We used cAnt-Miner algorithm because central nervous system microarray gene expression dataset we use in this study has continuous values.
Central Nervous System Cancer dataset, provided by Pomeroy [17], contains the expression levels of 7129 genes. Each sample was obtained from brain tissues and was analyzed using Affymetrix microarrays. This dataset contains two subtypes of cancer, namely classic medulloblastomas (CMD) and desmoplastic medulloblastomas (DMD). After data preprocessing, 857 genes remain. The source of the 857 gene expression measurements is publicly available at [18]. Central Nervous System Cancer dataset is available at Schliep lab bioinformatics Repository of Rutgers University contains 857 genes with one class attribute. The dataset includes numeric attributes. The class shows two subtypes of cancer named CMD and DMD. The dataset contains 34 samples belonging to two different target class. Table 1 shows the summary of the characteristics of the dataset.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Comparison</th>
<th>Class</th>
<th>Gene</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Nervous System Cancer</td>
<td>Tumor Subtypes</td>
<td>2</td>
<td>857</td>
<td>34</td>
</tr>
</tbody>
</table>

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

In this study, we compared the efficiency of the classification methods including; SVM, OneR, J48 Decision Tree, MLP, RBFNetwork and cAnt-Miner methods for the prediction of cancer risks. We used improved and modified Weka [19] software for applying classification on dataset. The classification accuracy is used as the performance measures. We transformed data into the format arff for Weka. At first, feature selection method was used to find relevant features in the central nervous cancer dataset and then, classification algorithms were applied to the selected features to evaluate the algorithms. Thirty features (genes) were selected by the feature selection algorithm. To select an important subset of genes from thousands of genes is pretty arduous. That’s why, gene selection becomes the most needed requirement for a diagnostic classifying system. For this reason, many researchers have applied different techniques to select a small subset of informative genes that can classify different subgroups of cancers accurately. The same experiment was repeated for six classifiers. The classification methods called statistical and artificial intelligence-based were applied to the dataset by performing feature selection and we tested the accuracy of our classification methods with 10-fold cross validation. The results of classification methods have been shown Figure 2.

According to Figure 2, Multi-Layer Perceptron (MLP) has the best performance among classification methods which performed on central nervous system microarray gene expression dataset with 97.06%. RBFNetwork and cAnt-Miner have the best results respectively, with 94.12% and 92.50% after MLP. SVM and OneR have the worst performance, with 73.53% in the experimental study.

As it is shown in Figure 3, the average performance of artificial intelligence-based methods is better than the average performance of statistical methods. Approximately, the average performance of artificial intelligence-based methods is 22.09% more than the average performance of statistical methods. Artificial Intelligence-based classification methods performed very well on Central Nervous System microarray cancer with, 94.56%. However, the average of statistical methods is less
than the average of artificial intelligence-based methods, with 83.33%.

V. CONCLUSION AND FUTURE EXTENSIONS

In this paper, we have conducted a comparative study of the classification methods for microarray data analysis on publicly available dataset including microarray central nervous system cancer dataset. Firstly we applied Correlation-based Feature Selection (CFS) which is method of dimension reduction on microarray dataset and then we compared the performances of six classification methods, namely Support Vector Machine (SVM), OneR, J48 Decision Tree, Multi-Layer Perceptron (MLP), Radial Basis Function Network (RBFNetwork) and cAnt-Miner on central nervous system dataset by using control parameters most commonly used in the literature. In conclusion, the experimental results show that the artificial intelligence-based classification methods have higher accuracy than the statistical classification methods. In the future, we will study on control parameter optimization of classification methods and then we will compare results of classification methods with parameters most commonly used in the literature and with optimal control parameters.

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Route Planning for Multiple Unmanned Aerial Vehicles (UAVs) with Parallel Genetic Algorithm on GPU Using CUDA

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Abstract—Unmanned Aerial Vehicles (UAVs) are designed as alternative solutions to traditional aerial vehicles controlled by human on-board. Recent advances in robotic and communication technologies have enabled UAVs to become convenient platforms for various missions from aerial surveillance to combat operations. Today, most of the efforts on UAV technologies from scientific and industrial communities are focusing on autonomy to provide self-decision skills to UAVs particularly on their mobility. In order to execute a certain mission effectively in the shortest possible time, an optimal pre-defined route plan which regulate the mobility of UAVs is required. Moreover, for multi-UAV systems, which consist of more than one UAVs perform their tasks in collaboration, this pre-defined route plan should be updatable during the mission in order to make the system fault tolerant. Route planning for multi-UAV systems is NP-hard problem which is also known as multiple traveling salesman problem (mTSP). Given a set of waypoints, multi take-off points for all UAVs, and a cost metric, the objective of the problem is finding a set of routes for a given number of UAVs so as to minimize the total cost. It is obvious that increase in the number of waypoints or UAVs cause exponential increase in search space. In order to find a solution with good quality from this huge search space within a reasonable amount of time, evolutionary algorithms and parallel computing techniques can be used. In this study, it is aimed to find near-optimal route plans for multi-UAV systems. The objective function used in this study provides that all individual routes of UAVs to be close each other as possible. The algorithm is implemented on GPUs using NVIDIA’s parallel computing platform, Compute Unified Device Architecture (CUDA). The efficiency and the effectiveness of the proposed parallel GA approach are demonstrated through simulations under different scenarios.

Keywords—parallel genetic algorithm, CUDA, multi-UAV systems, multi-TSP.

I. INTRODUCTION

The aviation is a discipline that doesn’t accept risks. Lots of R&D (Research and Development) activities has been made to decrease the risk factor to the lowest level and eradicate the risk at the end. The top of this activities is unmanned aerial vehicles (UAV). Technological investments and autonomous systems demonstrate that conventional air platforms are going to replace with unmanned aerial vehicles. Thus, people leave the platform will form the core of these systems that control program and structure.

It is aimed to improve the abilities of autonomous movement by calculating the routes fastly and effectively that unmanned aerial vehicles follow in this study. According to Scholer [11], autonomy consists of six parts that are mission distribution, hazardous area detection, route planning, avoidance of collision, generation of trajectory and vehicle control. By increasing autonomy, the stress on the operator decreases and it provides an environment that can be used by lots of unmanned aerial vehicles. Therefore, while data obtained by using only one UAV takes a long period of time, using multiple UAVs simultaneously may provide time efficiency.

Using a big UAV at the duties is not economic. Besides, using the smaller UAVs together that is equipped with payload increases the success of the duties. The problem is that calculate the routes of lots of UAVs both accurately and fastly. This problem is in the NP-Hard category according to the target points that will be gone. In this structure that can be named as the traveling salesman problem, increasing the target points that form the field of problem means that increasing the calculating time exponentially that is required for route planning. So, genetic algorithm offers a good solution in an acceptable time as the other evolutionary solution methods.

The time that genetic algorithm requires to find the solution increases with increasing the number of target point. In this situation, the information of route that UAVs, which is controlled simultaneously, need must be calculated in a shorter time. To attain the requiring time we must ensure that the algorithm of finding route process in parallel. Briefly total process time can be shortened by calculating in parallel, using the parts of program that don’t effect each other in lots of operation simultaneously and gathering the results. On account of requiring equipment, using the GPU cores that works at low frequencies unlike the high frequency CPU cores and has lots of in its is eligible for parallel calculating.

In this study, taking advantage of the power of the NVIDIA’s CUDA architecture, it is aimed to adopt the genetic algorithm approach to solve route planning problem for multiple UAVs. By this way, it is intended to find near-optimal route plans for multi UAV systems. All UAVs are assumed to be resided at different locations. One of the goals in this study is making all individual routes of UAVs to be close as possible. For this reason, the objective function used
in this study preferred from a study conducted by Gomez et al. [12]. The proposed genetic approach for multi UAV systems is implemented using on GPUs using NVIDIA’s parallel computing platform, Compute Unified Device Architecture (CUDA). The efficiency and the effectiveness of the proposed parallel GA approach are demonstrated through simulations under different scenarios.

The rest of the study is arranged at this array: At the second part, the basic information is given about the multiple traveling salesman problem and genetic algorithm. The other part, the similar studies is expressed. At the fourth part, CUDA architecture is explained. At the fifth part, the designing system is explained. At the other part, test results and comparisons is expressed. Finally, a brief explanation is made about the result and next studies.

II. BasiCS

A. Multiple Traveling Salesman Problem (mTSP)

In this study, it is observed that m number of UAV control n number of target points and turn back to the initial point again. This problem is defined as a generalization of widely known travelling salesman problem which more than one salesman is allowed. It is called as multiple traveling salesman problem (mTSP). Given a set of points, m depots where m salesmen are located, and a cost metric, the objective of mTSP is to determine a route for each salesman such that the total tour cost is minimized and that each city is visited exactly once by only one salesman. In mTSP, all of the routes must start and end at the same depot and each city must be visited exactly once by only one salesman. Sorting targets in the best order is not enough to get the optimal solution. It is also imported that which point is assigned to a salesmen [1].

Kara and Bektas [7] have provided a number of variations on the mTSP by presenting a mathematical model. With this model, sub-tour creation is prevented by detecting neighbors counts to visit.

B. Genetic Algorithm

Genetic algorithm can be defined as similar to the evolution observed in nature. Because it provides an heuristic search method, it does not necessitate to search all solution space of the problem. The terms used in this algorithm are very similar to the ones in biology. Some of these terms are chromosome, generation, choosing parents, crossover, mutation, etc.

In GA, each candidate solution represents chromosomes. Each chromosome is organized as an array of genes. In addition, a number of chromosome forms a generation. In this regard, chromosomes in the generation are sorted in terms of their solution quality according to fitness function. Each generation forms a new generation using GA operators such as crossover and mutation. As a result of new generations, the population becomes more qualified having individuals with better fitness values.

Fundamental phases of GA is shown in Figure 1.

III. RELATED STUDIES

Dantzig and Ramser [4] have provided an algorithmic approach to Vehicle Routing Problem (VRP) which is represented as in mTSP model by considering transport costs of vehicles. The main objective here was the minimizing the total cost by using Vehicle Routing Problem (VRP). This study is considered as the first study of VRP which is still agreed to be used in today’s vehicle systems.

In a study conducted by Ercan and Gencer [5], route plans for UAVs have been accepted as VRP and their types have been inspected and classified according to the needs.

Sahingoz [10] have proposed a flyable route which fits to multiple UAV’s maneuver angle in his study. The route is calculated with the genetic algorithm and the solution is produced in a faster way. In order to make the route flyable, Bezier curves are used in his study.

In another route planning study, Karakaya [8], has provided multiple Traveling Salesmen Problem approach to detect minimum count of UAV to spy a single target and to obtain a near-optimal route. The Ant Colony Optimization (ACO) Algorithm is used in his work. With a single vehicle base, considering the range limitations and coordination’s of targets 20% saving is achieved in the number of used unmanned vehicle number.

Ergenze and Leblebicigolu [6] have studied on the most efficient way that unmanned vehicles can obtain information from the desired locations. It is aimed to solve Traveling Salesmen Problem by staying away from the restricted regions. Matlab’s genetic algorithm tools have been used for the calculation of the route.
Valero et al. [12] have made the route planning using genetic algorithm for robots which are planned for the service to the patients. The scenarios which have 2, 3, 4, and 5 robots have been tested for the problem areas which have 30, 40, and 50 targets.

Cekmez [3], [2] and the others revealed that the route planning of one UAVs can be calculated faster by operating ACO and genetic algorithm on GPUs in parallel.

IV. CUDA ARCHITECTURE

This section describes the CUDA architecture through the example of the GeForce GTX 480 GPU card, which is used in our experiments.

In terms of hardware, CUDA GPUs are regarded as two level shared-memory machines. Processors in a GTX 480 are grouped into streaming multiprocessors (SMs). Each SM consists of 32 processors. The GTX 480 has 15 SMs. Therefore, the GTX 480 is equipped with total of 480 processors. CUDA is highly multithreaded architecture that allows a maximum of 1536 concurrent threads per SM. Hence, the GTX 480 can run a maximum of 23040 threads concurrently. Processors in a SM can exchange data via fast shared memory. On the other hand, data exchange between SMs can be performed via VRAM. VRAM is also like main memory for processors. So, code and data in a CUDA program are basically stored in VRAM.

CUDA programming model is one of multi-threaded programming models. In the following, we describe an overview of CUDA programming model using Fig. 2.

In a CUDA program, threads form two hierarchy: a grid and thread blocks. A thread block is a set of threads. A thread block has dimensions 1, 2, or 3. A grid is a set of blocks with the same size and dimension. A grid has dimensions 1 or 2. Each thread executes the same code specified by the kernel function. A kernel function call generates threads as a grid with given dimension and size. The reason why threads form two hierarchy is as follows. Threads in a thread block can share data efficiently via shared memory. However, the maximum number of threads per block is limited to 1024. So, if more than 1024 threads are required, we have to partition threads into several thread blocks with the same size.

V. PARALLEL GENETIC ALGORITHM

A parallel genetic algorithm was designed for multiple UAV route planning in this paper. Each solution in the genetic algorithm is named as chromosome. A cluster formed by these chromosomes is named as a population. After crossover and mutation over the members, the population, which is formed randomly at the beginning, has become a more acceptable situation. We express every candidate solution with a chromosome in our algorithm. We evaluate the quality with a fitness function which we determined. Algorithm stages, parallel design, and performance comparison according to the results will be explained in detail at the next sections.

A. Codification of The Chromosome

To make the route solution of multiple UAVs, it is required that number of UAV and number of target must exist in the candidate solution (chromosome). Therefore, we can see that which UAV will follow which route. In our study on one chromosome, number of UAV is shown with the values between [0, m – 1] and number of target is shown with the values between [m, m + n – 1] [12]. Every chromosome must be started one value showing a UAV. Providing that the index repetition does not occur, the sequence that comes after index of UAVs shows the route that UAV follows.

For example, the sample chromosome structure provided below shows route plans for 3 UAVs for 12 targets:

\[ 2-5-7-8-11-0-4-6-10-3-9-1-12-14-13 \]

In the solution:

- UAV 0 : 4-6-10-3-9
- UAV 1 : 12-14-13
- UAV 2 : 5-7-8-11

route is followed.

B. Calculation of The Fitness Value of Chromosome

It is required that the total route distance has to be its minimum value at standard mTSP. However, in our case, it is different from the standard mTSP. For route planning problem for multiple UAVs, it is required that duty execution time must be its minimum level. So, we can reduce the duty time by shortening UAV’s routes that has the maximum route distance in the candidate solution.

We want to minimize the total route distance (1st term in Eq. 11) and maximum subtour distance (2nd term in Eq. 11) in our study. Besides we provide that the route distance of every UAV to be close to each other by trying to increase the maximum base tour distance (3rd term in Eq. 11) [12].

\[
Fitness(ind_i) = \sum_{i=0}^{m-1} +0.9*\max(R_i) - 0.9*\min(R_i) \quad (1)
\]
shows the number of UAV, $R_i$ shows the total route distance which is charged to the UAV in the function.

C. Establishment of The Initial Population

In this phase, the initial population members build up with the threads. Threads create the initial population according to the index number that they have enhanced randomness. Thereby, it is produced quickly from each other as different candidate solutions. In addition, the prospect of going local optimum which is one of the missing side of genetic algorithm is reduced.

D. Parallel Evolution Process

Our approach is different from the algorithm proposed by Gomez et al. [12] in that we adopt the GA to CUDA GPUs in order to take the advantage of massively parallel programming. With our parallel GA approach, we provide significant increases in computing performance owing to parallel compute mechanism of NVIDIA GPUs.

- Initial population is created by an approach is increased randomness using time more efficiently. Here, working in parallel random number seed produced by each thread, mix the points of the problem with the random numbers to produce population that contains many different chromosome.
- Our work have local optimization step. This is provided as an alternative way to avoid local optima.

Elitism which is part of this process, parent selection, crossover, mutation, and local optimization is performed simultaneously by each thread.

**Elitism:** It is intended to protect the elite individuals with the Elitism. An individual which has a suitable previously determined value, displaced to the next population. Each thread between the index number 0 and 31 will transfer individual concerned to the next generation.

**Parent selection:** Two members selected randomly in the population to form the remaining members of the population. Eligibility value is better kept as the first parents. Similarly, the second parent is selected too.

**Crossover:** Creating a new individual which has the characteristics of selected individuals. The individual is produced that the thread which select Parent will settle the represents index number. This study uses *one point crossover*.

**Mutation:** That is the stage where genetic algorithms gets his actual power and genetic diversity is maintained. Swap mutation technique is used here. Changes in chromosome mutates at a rate of ten in thousand within the algorithm may allow access to the global optimal.

**Local optimization:** It is used 2-opt local optimization to prevent produced individuals from unsuitable results. Thereby the algorithm has produced much better results.

Crossover and mutation can’t reach the best results every time. At the end of the iteration to reduce the possibility of convergence of poor results can be found in solutions called local optimization structure aimed at removing crosslinks. The 2-opt basically removes two edges from the tour, and reconnects the two new sub-tours created. 2-opt local optimization is used as shown in Figure-3 in this study.

Finally, population which passed this stage is ranked according to the fitness value of individuals. This processes continue until it reaches the criteria finalization specified maximum number of iterations which is 200.

VI. EXPERIMENTAL RESULTS

A. Performance Comparison Between GPU and CPU

GA is implemented both on CPU and GPU for performance comparisons. Table I shows some specifications of the hardwares. Sequential genetic algorithm and the introduced parallel genetic algorithm are run on this system. All GPU tests are executed with 5120 threads. CPU version tests are executed with 512 population size. Elitism size is set to 32 because of the number of the warp size. At the same time maximum 32 threads are processed at the GPU. The parameters of the genetic algorithm chosen in this study are as shown in Table II.

Multi-UAV system is considered as consisting 4 UAVs. Data sets with 52 and 100 and waypoints are used in the experiments. As it is presented in Fig.4 and Fig.5, GPU implementation provides better total travel cost values for the same number of iterations. It is therefore important to note that GPU implementation of genetic algorithm provides better solutions as compared to serial CPU implementation.
TABLE II
TEST PARAMETERS OF THE GENETIC ALGORITHM

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of the target points</td>
<td>52 / 100</td>
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<tr>
<td>Number of the UAVs</td>
<td>4</td>
</tr>
<tr>
<td>Population Size</td>
<td>512</td>
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<td>Elitism</td>
<td>32 individual each generation</td>
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<td>Parental Selection</td>
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<tr>
<td>Mutation Rate</td>
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<tr>
<td>Local Optimization Type</td>
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<td>Number of iteration</td>
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TABLE III
EFFECTS OF NUMBER OF THREADS ON AVERAGE CONVERGENCE TIME

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Num. of UAVs</td>
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</tr>
<tr>
<td>Mutation Rate</td>
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<td>Ending Criteria</td>
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<td>Num. Threads</td>
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<td>Model of the GPU card</td>
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</tbody>
</table>

TABLE IV
TEST SETS.

<table>
<thead>
<tr>
<th>Name of Data Sets</th>
<th>Num. of Waypoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>kroA100</td>
<td>100</td>
</tr>
<tr>
<td>kroB150</td>
<td>150</td>
</tr>
</tbody>
</table>

surveillance data. At this point, it is required to find near optimal individual routes for UAVs in the system. In order to compute these routes as soon as possible, proposed parallel genetic algorithm is implemented on CUDA GPUs. It is assumed that proposed algorithm is performed at ground station which have NVIDIA’s CUDA capable GPU cards. After the computation each route plans are send to respective UAVs.

In this simulation study, it is aimed to observe the effects of number of population used in the algorithm on average convergence time. It is important to note that number of population is equal to the number of threads used in the algorithm. The optimum number of threads can be found in this way.

The parameters used in this simulation study are presented in Table III above. This study is performed on TSPLIB [9] data sets whose details given in Table IV.

Fig. 4. Comparison of CPU and GPU performance for 52 waypoints using 4 UAVs.

Fig. 5. Comparison of CPU and GPU performance for 100 waypoints using 4 UAVs.

B. Effects of Number of Threads on Average Convergence Time

In this paper, it is consider that UAVs are planned to visit pre-defined geographical locations in order to obtain

Fig. 6 shows the results for NVIDIA’s GTX480 graphic card. As it is shown in the figure, average convergence time decreases up to a certain point. This is because hardware resources can be utilized up to a certain number of threads which is determined as 5120 threads. However, when the number of threads are kept to increase, average convergence time starts to increase due to the insufficient hardware
resources of graphic card. As it is presented in Section IV in detail, each CUDA capable graphic cards consist of a constant number of streaming multiprocessors (SMs). Also in each SM, there are a certain number of CUDA cores (streaming processors-SPs). Additionally, the number of resident warp executed by each SM simultaneously is also constant. Each warp has 32 threads for all CUDA architectures. Within this context, the maximum concurrent number of threads executed by SMs for CUDA capable GPUs can be calculated as: Max. Number of Threads = Total Number of SM x Resident Warp x 32 threads.

The number above is the maximum number of threads whose resources can be stored on-chip simultaneously. In CUDA architecture, the hardware switches between warps constantly to help hide the large latency of memory accesses. However, even each SM has a certain number of resident warp, it can only issue instructions from a small number of warps at each clock cycle. Therefore, as it is shown in Figure 6, in most cases, while it can be launched more threads concurrently on the GTX480 the optimal value of number of threads is lower.

This result shows that round-robin thread scheduling mechanism is used in CUDA architecture in order to meet the increasing number of threads. In this context, threads waiting in ready queue cause increased average convergence time. As a result, the lowest average convergence time obtained in this simulation study also shows that the optimum hardware utilization for the GTX480.

C. Effects of objective function on average flight cost

As it is presented in Section V, in order to obtain individual routes for each UAV as close as possible, a modified objective function is used in genetic algorithm. In this simulation study, the objective function, which is used for route cost calculation, is analyzed. By this way, the objective function do not consider traditional point to point Euclidian distance used in classical TSP problems. The parameters used in this simulation study are presented in Table V. The objective function used in this study adds additional cost value according to penalty factor chosen. Therefore, each individual routes for UAVs are made close each other in terms of total flight cost.

Figure 7 shows the result of effects of objective function on average total flight cost. The detailed results are shown at Table VI. NVIDIA’s GTX480 graphic card is used to observe the behaviour of objective function on kroA100 data set. As it can be understood from the figure, penalty factor is increased gradually from 0 to 0.9. Vertical axis shows the average flight routes for each UAVs. It is obvious that while average flight route cost tends to maintain its stability, the standart deviation of these average values tends to decrease. Standart deviation of these average values shows the quality of individual flight route similarities in terms of route cost. Low standart deviation indicates high similarty among individual flight routes in terms of route cost. This is because as the value of penalty factor is increased, additional cost applied to total cost is also increased. The acceptance probabilty of the flight route is decreased in this way due to the low solution quality. Consequently, choosing high penalty factor enables to obtain individual flight routes as close as possible.

VII. CONCLUSION

Today, most of the efforts on UAV technologies from scientific and industrial communities are focusing on autonomy to provide self-decision skills to UAVs particularly on their mobility. An optimal pre-defined route plan which regulate the mobility of UAVs is required in order to execute a certain mission effectively in the shortest possible time. Moreover, route planning for multi-UAV systems is NP-complete problem which is also known as multiple traveling salesman problem (mTSP). It is quite known that increase in the number of waypoints or UAVs cause the exponential increase in the search space. Evolutionary algorithms and

---

**TABLE V**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Num. of UAV</td>
<td>4</td>
</tr>
<tr>
<td>Num. of Waypoint</td>
<td>100</td>
</tr>
<tr>
<td>Mutation rate</td>
<td>20%</td>
</tr>
<tr>
<td>Ending Criteria</td>
<td>200</td>
</tr>
<tr>
<td>Num. of threads</td>
<td>5120</td>
</tr>
<tr>
<td>Model of the GPU card</td>
<td>GeForce GTX480</td>
</tr>
<tr>
<td>Penalty Factors</td>
<td>[0 , 0.3 , 0.6 , 0.9]</td>
</tr>
</tbody>
</table>

**TABLE VI**

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Penalty Factor</th>
<th>Average Flight Cost</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-1</td>
<td>0</td>
<td>5670.1</td>
<td>7635.8</td>
</tr>
<tr>
<td>State-2</td>
<td>0.3</td>
<td>5994.6</td>
<td>904.7</td>
</tr>
<tr>
<td>State-3</td>
<td>0.6</td>
<td>5993.1</td>
<td>739.3</td>
</tr>
<tr>
<td>State-4</td>
<td>0.9</td>
<td>6153.1</td>
<td>590.4</td>
</tr>
</tbody>
</table>
parallel computing techniques can be used in order to find a solution with good quality from this huge search space within a reasonable amount of time.

In this study, it is aimed to adopt parallel genetic algorithm on CUDA capable GPUs to compute flight routes for multi depot multi-UAV systems efficiently. The objective function used in this study has provided that all individual routes of UAVs to be close each other as possible. GPU performance of proposed genetic approach is compared with the CPU version. Simulation studies shows the efficiency of proposed parallel GA approach on CUDA platform under different scenarios. As a future work, it is planned to improve the performance of the parallel genetic algorithm by considering CUDA hardware performance issues. It is also intended to conduct simulation studies on large scale mTSP systems.

REFERENCES

Training ANFIS Using Genetic Algorithm for Dynamic Systems Identification

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Abstract—In this study, the premise and consequent parameters of ANFIS are optimized using Genetic Algorithm (GA) based on a population algorithm. The proposed approach is applied to the nonlinear dynamic system identification problem. The simulation results of the method are compared with the Backpropagation (BP) algorithm and the results of other methods that are available in the literature. With this study it was observed that the optimisation of ANFIS parameters using GA is more successful than the other methods.

Keywords— neuro-fuzzy, ANFIS, genetic algorithm, system identification

I. INTRODUCTION

System identification is a model generating process that is developed to predict the behaviour of a system between its input and output signals. The approaches based on the fuzzy neural networks and artificial neural networks are among the methods that are used commonly for the dynamic systems identification. However, due to some of its superior features, studies towards using ANFIS for the purpose of dynamic system identification, have started to increase gradually in the recent years [1-5].

Training the ANFIS model is basically the determination process of the optimal values for the model’s premise and consequent parameters. Derivative-based algorithms are commonly used for training of ANFIS. But there is a problem of getting stuck in a local minimum in derivative-based algorithms. In this context, various methods have been proposed in recent years in order to train ANFIS parameters. Some of these methods are artificial intelligence optimization algorithms and heuristic algorithms such as Genetic algorithm, PSO and Differential Evolution Algorithm that are not derivative-based [6].


In this study, an approach is presented towards the training ANFIS by using GA based on a population algorithm. The performance of the presented approach is tested on non-linear system and the results are compared with different methods. In the following section, the basic structure of ANFIS is introduced, in the third section, information about genetic algorithm is given, in the fourth section, information about the presented approach is given and the obtained results are given in the section 5.

II. ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM (ANFIS)

Adaptive Network-based Fuzzy Inference System (ANFIS) is a network model which Sugeno-type fuzzy system is combined with neural learning ability. The main aim of ANFIS is to optimize the parameters of the equivalent fuzzy logic system by using input-output data sets via a learning algorithm. Parameter optimization is carried out in such a way that the error value between the actual output and the target output to be minimum.

ANFIS contains two parameters as antecedent and consequent parameters. Those two parameter types connect the fuzzy rules to each other and training of the model is provided with the optimization of these parameters. ANFIS basically consists of five layers. A basic ANFIS structure consisting of two inputs and one output is given in Fig. 1.

Fig. 1 A basic structure of ANFIS [9]

A. Layer 1

This layer is named as the fuzzification layer. The signal that is obtained from each node is transferred to the other layer. In this layer, for the outputs of the cells, \( O_i \), Equation (1) and Equation (2) are given [10].

\[
O_i = \mu A_i(x) \quad i = 1,2 \\
O_i = \mu B_{i-2}(x) \quad i = 3,4
\]
In here, $A_i$ and $B_i$ are any membership functions belong to the inputs, $\mu_{A_i}$ and $\mu_{B_i}$ are membership degrees that are calculated for this function. For the bell-shaped membership function $\mu_{A_i}$ is calculated with the equation below.

$$\mu_{A_i} = e^{-\frac{(x-c_i)^2}{2\sigma_i^2}} \quad i = 1, 2 \quad (3)$$

In here, $\sigma_i$ and $c_i$ are sigma and central parameters of the membership function respectively.

**B. Layer 2**

This layer is named as the rule layer. Each rule’s firing strength is calculated with the membership degrees that are coming from the previous layer.

$$O_{3i} = w_i \cdot \mu_{A_i}(x) \cdot \mu_{B_i}(y) \quad i = 1, 2 \quad (4)$$

**C. Layer 3**

In this layer which is named as the normalisation layer, each rule’s normalised firing strength is calculated.

$$O_{si} = w_i = \frac{w_i}{w_1 + w_2} \quad i = 1, 2 \quad (5)$$

**D. Layer 4**

This layer is the defuzzification layer. Output value for each rule is calculated using the value of firing strength from previous layer.

$$O_{ai} = w_i \cdot f_i = w_i \cdot (p_i x + q_i y + r_i) \quad i = 1, 2 \quad (6)$$

**E. Layer 5**

This is the sum layer. ANFIS’s output is obtained by collecting the output values belong to the each rule that are obtained in defuzzification layer.

$$O_{si} = f = \sum w_i f_i = \frac{\sum w_i f_i}{\sum w_i} \quad i = 1, 2 \quad (7)$$

### III. GENETIC ALGORITHM

Genetic Algorithm (GA) which its fundamental principles are set forth by John Holland in 1970’s, is implemented with success on many problem types [11]. GA is a heuristic algorithm which is used for being able to find exact or approximate results in optimization or search problem. This algorithm is developed by being inspired from the techniques in the evolutionary biology such as inheritance, mutation, selection and crossover. GA can be implemented quite effortlessly even on the multidimensional problems with large-size search space and also with too many number of variables.

GA is a population based optimization algorithm. Equivalent of the candidate solutions that generate the population is chromosomes. Due to the various evolution processes, these chromosomes transform into the solution candidates that represent better results. This process is maintained until reaching an acceptable compliance value or until meeting the criteria such as pre-determined processing time or generation number. Basic steps of the Genetic Algorithm are given in Fig. 2.

1. Generate random population of $n$ chromosomes
2. Evaluate the fitness of each chromosome
3. Create a new population by repeating following steps until the new population is complete
   i. Select two parent chromosomes from a population according to their fitness
   ii. With a crossover probability cross over the parents to form new offspring
   iii. With a mutation probability mutate new offspring at each locus
   iv. Place new offspring in the new population
4. Use new generated population for a further run of the algorithm
5. If the end condition is satisfied, stop, and return the best solution in current population
6. Go to step 2

**IV. TRAINING ANFIS USING GA**

In this section, GA usage for updating ANFIS parameters is explained. ANFIS has two parameter types that have to be updated. These are premise parameters and consequent parameters. Premise parameters belong to the gauss membership function that is given as $\{a_i, c_i\}$ in Equation (3). The total number of the premise parameters is equal to the sum of the parameters in all membership functions. Consequent parameters are the ones that are used in defuzzification layer, shown in Equation (6) as $\{p_i, q_i, r_i\}$.

The method that is suggested in this study is applied to the dynamic system identification problem. For the error value between the output obtained from ANFIS and the output obtained from non-linear dynamic system to be minimum, ANFIS parameters are optimized with GA. Block diagram showing this structure is given in Fig. 3. RMSE error function which is obtained by using Equation (8), is used for determining the error value of the solution. $\bar{y}_i$ is used in Equation (8), is showing the output obtained by ANFIS at the time $i$ and $y_i$ is showing the actual output of the system. $N$ is showing the instance number used in the application.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(y_i - \bar{y}_i)^2}{N}} \quad (8)$$

The selection of the input array which will be used in training is important on the success of training. The elements of the input array are usually chosen from sinusoidal and random input values [13]. In the carried out simulation studies within this study, $u(k)$ input signal array which has proper distribution, randomly generated in the range of $[-2, 2]$ is used.
V. SIMULATION RESULTS

In this section, Applications have been performed by using non-linear dynamic system for the training ANFIS with GA. In order to measure the performance of the system 250 input and output data sets are generated. 200 of these data sets are used for training, the remaining 50 are used for the test.

For the dynamic system, that is going to be modelled, ANFIS structure that consists of 3 inputs and 1 output is created respectively. For each of the input of created ANFIS structure, gauss membership function with 2 parameters is used. Therefore there are 2^n rules in the used ANFIS model [14]. In this way, ANFIS structure consisting 12 premise parameters and 32 consequent parameters with 8 rules is used for the system.

In the study, many attempts have been made in order to decide upon the various parameter values that are required for GA. As a consequence of these attempts, population size is chosen as 200, crossover rate is chosen as 0.8 and mutation rate is chosen as 0.01.

Besides, the performance of the suggested approach is also compared with the results taken from the literature, which belong to the Elman feedback artificial neural network that is commonly used in the identification of the dynamic systems [15,16]. In the considered studies, Kalinli has suggested an approach based on training Elman network by using Tabu Search Algorithm (TS), SA algorithm and Parallel Tabu Search Algorithm (PTS) for the identification of dynamic systems and achieved more successful results than the traditional BP algorithm [15,16].

Sample non-linear system which is used for simulation belongs to a simple pendulum, swinging through small angle that is taken from [15] and defined with Equation (9). The system’s discrete time definition is as follows:

\[ y(k) = A_1 y(k-1) + A_2 y(k-2) + A_3 y^3(k-2) + B_1 u(k-2) \]  

where, \( A_1 = 1.040000, \) \( A_2 = -0.824000, \)  
\( A_3 = 0.130667, \) \( B_1 = -0.160000 \)

\textbf{RMSE} error values that are obtained following the simulation studies, and the error values belong to different methods and that are taken from the literature are given in Table 1. From the results that are given on Table 1, it is clearly seen that the performance of the approach suggested in this study has quite high success comparing to the other methods. Standard deviation for the training and testing processes of the error values that are obtained in 15 different attempts towards training ANFIS with genetic algorithm is found as 0.0032 and 0.0022 respectively. The low standard deviations show that \textit{RMSE} values are close to each other, so it means that the results are reliable. The system that belongs one of the attempts towards training ANFIS with GA and the answers of ANFIS model are given in Fig. 4.

<table>
<thead>
<tr>
<th>Model</th>
<th>Train (\textit{RMSE}_\text{Avg})</th>
<th>Test (\textit{RMSE}_\text{Avg})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elman – PTS [16]</td>
<td>-</td>
<td>2.8318E-02</td>
</tr>
<tr>
<td>ANFIS - BP</td>
<td>7.99112E-03</td>
<td>9.60747E-03</td>
</tr>
<tr>
<td>ANFIS – GA</td>
<td>8.69121E-03</td>
<td>8.32214E-03</td>
</tr>
</tbody>
</table>

VI. CONCLUSIONS

It has been seen that the best training and test error values obtained are found with the suggested method. Following the studies, finding the admissible \textit{RMSE} error value shows that the training of ANFIS using GA for identification of non-linear systems is quite effective. Besides, the results with the low deviation value has been obtained within the suggested method. Having low deviation value shows that \textit{RMSE} error values obtained from trainings started with different initial solutions are close to each other which means the results are reliable. Also, by reason of the fact that Genetic algorithm does not have restrictions as the derivative-based algorithms have and it is easily applicable on the problems, it is assessed that ANFIS model can be used on its applications for different problems.

ACKNOWLEDGMENT

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DSMAC: Deadline Sensitive Medium Access Control Protocol for Delay Tolerant Network based Multiple Unmanned Aerial Vehicle Systems

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Abstract—Fast moving electro-mechanical and wireless communication technologies have made it possible to design and implement multiple unmanned aerial vehicle (multi-UAV) systems which promise more efficient and reliable ways to perform application-specific missions through their simultaneous execution capability and fault tolerant potential. In a typical surveillance-based multi-UAV application, each individual UAV collects required data from its area of interest and transfer it to a ground station (GS) through a shared communication link. In some challenging cases, e.g. in a hostile environment such as battlefield communication, which is unable to establish and maintain a reliable end-to-end communication link between UAV and the GS, Delay Tolerant Network (DTN) paradigm which is based on store-carry-forward data delivery technique can be applied. However, in such system, link layer packet collisions may occur because it is quite possible that multiple UAVs may arrive at communication range of the GS at overlapping times and need to transfer their data simultaneously. This paper presents deadline-sensitive medium access control (DSMAC) protocol designed for DTN based multi-UAV systems. The DSMAC protocol provides a non-preemptive medium access scheme in a centralized manner to make the medium free of collisions. The main objective is to enable UAVs to transfer their large amount of surveillance data as fast as possible to the GS by taking deadline-constrained data delivery requirement into consideration. Our protocol differs significantly from commercially available technologies such as 802.11, 3G or LTE in that deadline meeting rate is the main performance metric in our case rather than providing general connectivity and fair medium sharing among large number of UAVs. Simulation studies are conducted by using NS-2. Results show that DSMAC protocol provides considerable performance improvements in terms of average waiting time and deadline meeting rate when compared to PCF (Point Coordination Function) mode of widely used IEEE 802.11 technology.

Keywords— medium access control, delay tolerant networks, multi-uav systems, deadline sensitive.

I. INTRODUCTION

Recent developments in micro electro-mechanical systems and wireless communication technologies have enabled the realization of unmanned aerial vehicle (UAV) systems. Single-UAV systems, which consist of only one large UAV with powerful hardware, have produced at relatively high costs and provided successful results in many application areas for about last twenty years. On the other hand, much smaller UAVs can be produced at lower costs with the downsizing trend experienced in embedded systems today. The decrease in the size of UAVs brings out strict limitations over maximum take-off load capacity so that application-specific payloads used in these small UAVs have more limited capabilities. For this reason, required efficiency for some UAV applications cannot be achieved by using a single small UAV. In this context, it is considered that a multi-UAV system, which is composed of multiple small UAVs, may offer more efficient solutions by performing jointly missions such as surveillance, reconnaissance, monitoring etc. Using multiple UAVs allows establishing a fault tolerant structure along with providing task completion in a shorter period of time owing to the advantage of its capability of simultaneous task execution in multiple locations. Also, potential coordination capability of multiple autonomous UAVs may provide to accomplish missions that no individual UAV can accomplish on its own. However, multi-UAV approach brings many distinctive challenging design problems.

Communication is one of the most important design problems for multi-UAV systems. The main objective for a multi-UAV application which performs a typical reconnaissance/surveillance mission is increasing success rate of the mission and providing time efficiency by distributing tasks on multiple UAVs. It is required for each individual UAVs in the system to collect application-specific data from its own area of interest and transfer it to a ground station (GS) as soon as possible for further data processing phases. In such applications, it is difficult to setup a reliable end-to-end communication link between UAVs and the GS in cases which locations to be visited for data collection remain out of the communication range provided by the GS or, in more general terms, which there are some challenging conditions in the communication environment such as battlefield communication, disaster rescue etc.

For multi-UAV applications performing tasks which require collecting data in a certain operation area and then deliver it to a GS, it is obvious that there is no need for immediate or real-time data transmission in cases which the application-specific data has a certain degree of delay
tolerance. Clearly, for such cases, it is required to collect delay tolerant data from the operation area, store it into the on-board memory of UAVs, and carry it until reaching required wireless communication range for reliable connection with the GS. In this context, it is considered that using Delay Tolerant Network (DTN) [1] model, which have been developed for similar needs, may provide considerable advantages for such multi-UAV applications. The DTN based data delivery technique considered in this study for multi-uav systems is first proposed by Spyropoulos et al. [2] and it is also known as Direct Delivery. Fig.1 below illustrates a multi-uav system which performs its operation within the context of this simple single-copy DTN delivery scheme. UAVs, as source nodes, carry their application-specific data until they reach the GS.

DTN paradigm has been developed for abnormal network conditions where a reliable communication and a complete end-to-end connectivity between the data source and destination may not exist. Different from traditional networking approach, DTNs are characterized by long latencies, unstable network topologies, and inconsistent connectivity. With these characteristics, DTNs find places in such applications that traditional networks cannot work effectively, for example, data communications in rural area where communication infrastructure cannot be deployed or costly [3], disaster rescue [4], military/battlefield communications [5], etc.

Most of the research efforts on DTN in the literature focus on data delivery/routing schemes for different network scenarios assuming that mobile communication devices are distributed sparsely and network traffic is low. However, link layer packet collision problem in DTN-based applications is not considered in these studies. Within this context, a study conducted by Jindal et al. [6] shows that the packet collision problem should not be overlooked especially for densely distributed communication devices are on subject. In another study, Liang et al. [7] has proposed a DTN-friendly MAC protocol (DFMAC) which is developed for radio resource allocation for a DTN/WLAN integrated networks. In order to address the problem of large delay variance in underwater acoustic channel, Zhang et al. [8] has proposed a cluster based delay tolerant MAC protocol (CBDTP) for underwater wireless sensor networks which is based on predicating a value for a sensor node if its data were not received at the sink node instead of having the sensor node retransmit its data. In another study, Zhong et al. [9] has proposed UMACAW as another delay tolerant MAC protocol which utilize the rest time of RTS/CTS/DATA/ACK exchange period by taking advantage of long propagation delay in underwater channels. However, none of these efforts made on MAC protocols intended for DTN paradigm in the literature take deadline-constrained data delivery requirement into consideration.

For DTN based multi-UAV applications considered in this study, the problem of link layer packet collisions may occur when multiple UAVs arrive at the GS at overlapping time periods and attempt to transfer their data simultaneously, as it is shown in Fig.1. In general, COTS technologies such as IEEE 802.11, 3G, and LTE are used to overcome link layer packet collision problem for such applications. However, the main objective of these technologies is providing medium sharing as fair as possible for large number of stations. Although multi-UAV applications perform their tasks by using DTN model, there may still be some deadline constraints for collected data within certain scenarios. Therefore, the most important need for multi-UAV systems which perform their tasks under such scenarios is providing medium access for UAVs by taking deadline constraints of their data into account and data transmission without any interruption in order to ensure UAVs to continue their tasks as soon as possible. To the best of our knowledge, medium access in DTN has not been studied from this perspective before and this is the first research effort focusing on deadline sensitivity of channel allocation for DTN based multi-uav systems.

To address these needs, in this paper, a MAC protocol for DTN based multi-UAV systems is proposed which eliminates the link layer packet collisions, ensures UAVs to return their operation area as soon as possible by providing data transmission without suspending it because of any other possible transfer requests, and uses deadline information of collected data as a priority measure for medium access. Because the main criteria for medium access is deadline for transmission of data to the GS, the proposed MAC protocol is named as “Deadline-sensitive Medium Access Control” (DSMAC). DSMAC protocol provides a centralized medium access model using two different communication channel. Tests for DSMAC protocol are conducted by using NS2. DSMAC’s superiority over PCF (Point Coordination Function) [10] mode of widely used IEEE 802.11 protocol are analyzed through performance metrics such as average waiting time and deadline meeting rate. Simulation results show that channel allocation scheduling mechanism and centralized MAC model provided by DSMAC protocol outperforms IEEE 802.11 PCF in terms of average waiting time and deadline meeting rate for aforementioned multi-UAV applications.

The remainder of the paper is organized as follows. The protocol design issues and its operation details are described in Section II. Medium access scheduling mechanism of
DSMAC is provided in Section III. Performance evaluation and simulation results are presented in Section III. Finally, the paper is concluded in Section IV.

II. DSMAC PROTOCOL

In the following sections, we first present an overview of proposed DSMAC protocol to discuss the main objectives and then we provide the design issues of DSMAC with its operation details.

A. Overview

For a DTN based multi-UAV system considered in this study which performs a surveillance-based mission, UAVs are required to collect application-specific data from their area of interests, store data in their own on-board memory, and then deliver them to the GS by moving to it until they arrive at required communication range for reliable wireless connection. Clearly, there is a need for a MAC protocol in order to regulate medium accesses of UAVs in such cases that multiple UAVs arrive at GS for data transmission at overlapping time periods and attempt to access the medium simultaneously.

One of the most important limitations for UAVs is endurance capability. In order to utilize limited flight duration of UAVs within the context of data transfer to the GS, it is quite important to consider this fact at MAC level operations. Besides that, certain applications may necessitate specific amount of delay tolerance for data delivery rather than completely disregarding it even they perform under DTN paradigm. For these reasons, to assure effective usage of limited flight duration and timely data delivering, deadline-constraint data transmission to the GS as fast as possible must be effectively handled by an efficient MAC protocol mechanism. To this end, the main objectives of DSMAC protocol we design for DTN based multi-UAV systems are:

- creating a centralized channel allocation mechanism in order to provide contention-free medium access for UAVs,
- using two different communication channels for data and control frames to utilize data channel effectively,
- making channel allocation scheduling non-preemptive to avoid suspending ongoing transmission,
- taking record deadlines into consideration for channel allocation to increase the deadline meeting rate as much as possible

B. Design

DSMAC protocol is designed to provide a centralized MAC scheme for DTN based multi-UAV systems. Accesses to the medium are controlled only by the GS. It performs its operations as a coordinator while UAVs in the system are its associated mobile nodes. None of the UAVs has a direct access permission to the medium. UAVs are allowed to transmit their data only when the GS sends a special frame to them, which is called START. Fig.2 below shows the START frame format. It is important to note that Frame Control field which has a number of sub-fields such as protocol version, frame type/subtype, retry flag, etc. is inherited from the 802.11 protocol specifications due to its ease of NS2 implementation.

As it is shown in Fig.3, UAVs arriving at the GS wait for the START frame to start transfer their data to the GS. The GS, as a coordinator, is responsible to decide which UAV is allowed to use the channel first. The details of this decision process is described in Section III. Because UAVs are not allowed to access the channel freely, an ongoing transmission is not interrupted by other UAVs. Clearly, there is no contention among UAVs to gain the access to the channel due to the centralized mechanism of DSMAC. To this end, additional frame exchanges between the communication nodes in order to avoid packet collisions such in CSMA/CA are not needed in DSMAC protocol.

In DSMAC protocol, it is assumed to be used two different transceiver in UAVs with two antennas and their associated communication circuitry. One of them performs on data channel while the other uses control channel. It is also assumed that possible interference between two transceivers are resolved using a kind of digital signal processing methods or physical precautions.

It is clear that the GS has to be informed by UAVs in some way to notify that they have records to be transferred to the GS. In this regard, we introduce a term meta-info, which is a brief information of records to be transferred to the GS. Since the DSMAC provides coordinator initiated data transmission, this information is used by the GS to schedule
the channel allocations properly and to send a START frame to a UAV. The control channel mentioned above is used by UAVs to send their meta-info to the GS when they arrive. Thus, UAVs are able to send their data transfer requests using control channel without violating the data channel. Because the size of meta-info is quite small and the essential need for control channel is to provide a reliable communication link between UAVs and the GS, it is considered as a contention-based channel which can be implemented by using one of the COTS technologies such as XBee 802.15.4 [11] or Wi-Fi [10] modules. Data channel, on the other hand, is the channel allocated by the GS to a UAV for reliable data transmission using ARQ. Contention-free medium access for data transfer is provided using the data channel. Thus, DATA-ACK exchanges start between the UAV#1 and the GS. After a short time, as this frame exchange continues between the UAV#1 and the GS, UAV#2 arrives at GS and sends its meta-info using control channel as it is shown as red frames in the figure. In this way, the meta-info transmission does not disturb the ongoing data transmission. In order to notify the GS for last DATA frame, UAV#1 set a flag into the Frame Control field of DATA frame which is shown in the figure as a red marker on the end of the last DATA frame sent by UAV#1. The GS notices that it can send START frame to allocate the data channel to the UAV#2. To assure its last ACK frame as a feedback is received by the UAV#1, it waits for a \( t_D \) period of time before sending a new START frame to the UAV#2. Although the details of channel allocation scheduling performed by the GS is provided in Section III, at this point, it is important to note that the GS does not stop the current data transmission even that UAV#2 has a record with higher priority than the UAV#1 has. This is because the GS schedules channel allocations based on non-preemptive Earliest Deadline First service discipline as described later.

\[
t_D = TX_{ACK} + DSSS_{MAX} + TX_{DATA} + DSSS_{MAX}
\]

The time period of \( t_D \) used in NS2 implementation of DSMAC is calculated as below. It is the sum of transmission time of ACK frame (\( TX_{ACK} \)), maximum propagation time for ACK, transmission time of DATA frame (\( TX_{DATA} \)), and maximum propagation time for DATA. Additionally, in order to provide reliable communication between UAVs and the GS, retransmission timers for DATA packets sent by UAVs and START packets sent by the GS are also implemented in a similar way in NS2.

III. CHANNEL ALLOCATION SCHEDULING

As described before, DSMAC protocol provides a centralized channel access scheme. Access to the medium is completely controlled by the GS so the possibility of contention for the medium is eliminated. UAVs arrived at the GS send their meta-info using control channel. The GS uses meta-info to create an access priority plan by considering delivery deadlines of records. An example meta-info sent by a UAV to the GS is presented in Table I below.

<table>
<thead>
<tr>
<th>UAV Id</th>
<th>Record Id</th>
<th>Deadline (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>344</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>507</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>830</td>
</tr>
</tbody>
</table>

Channel access function implemented in the GS uses a service discipline based on Earliest Deadline First (EDF) [12] scheduling algorithm which is generally used in real-time operating systems. The channel access function places transfer requests into a priority queue. Whenever a data transfer is completed, the queue is searched for the transfer request which has minimum delivery deadline value for the
next data transfer. Unlike EDF, scheduling algorithm used in DSMAC is non-preemptive. This means the GS does not suspend ongoing data transfer to start another one. Although a newly received meta-info has a record with higher priority, which means a closer deadline value, current data transfer is waited for to end. The reason that we are using such non-preemptive mechanism for channel access service is limited flight duration of UAVs. It is important to note that one of the major objectives of DSMAC is to allow UAVs to continue their operation as soon as possible in addition to satisfy deadline constraints of the records.

It is better to present a case study to gain more insight regarding different scheduling mechanisms. To this end, we provide a sample transfer requests made by three UAVs in Table II.

<table>
<thead>
<tr>
<th>UAV Id</th>
<th>Record Id</th>
<th>Record Size</th>
<th>Transfer Time (sec)</th>
<th>Deadline (sec)</th>
<th>Request Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>D_1</td>
<td>60</td>
<td>120</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>D_2</td>
<td>40</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>D_3</td>
<td>10</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>D_4</td>
<td>20</td>
<td>110</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>D_5</td>
<td>30</td>
<td>170</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>D_6</td>
<td>50</td>
<td>130</td>
<td>60</td>
</tr>
</tbody>
</table>

Based on the transfer requests provided in Table II, Gantt charts and results for some performance measures are provided in Fig.6 and Fig.7 according to round-robin and non-preemptive EDF scheduling algorithms corresponding to 802.11 PCF and DSMAC, respectively. Gantt charts show the order of data transfers for corresponding scheduling algorithms. Performance measures used in this case study can be defined as:

- The **Waiting Time** is an amount of time a data transfer is waiting in the ready queue or sum of time waiting in ready queue.
- The **Turnaround Time** is an amount of time to complete a data transfer (time from first placed in ready queue to transfer completion).
- The **Response Time** is an amount of time it takes from when a transfer request is placed in ready queue until the first response is produced (not completion of transfer).
- The **Deadline Meeting Rate (DMR)** is the rate of satisfied deadline constraints of records.

If round-robin scheduling is applied to sample transfer requests provided in Table II, as it is shown in Fig.6, transmission of records is performed in a fragmental manner with the 10 sec quantum value. Because round-robin scheduling is a preemptive approach, it gives relatively high average times compared to non-preemptive EDF (Fig.7). The reason that we prefer to use round-robin scheduling mechanism to compare it with the scheduling algorithm used in DSMAC (non-preemptive EDF) is because it is used in 802.11 PCF.
PCF which also provides a centralized and contention-free medium access as DSMAC we propose.

![Fig. 7. Results for non-preemptive EDF scheduling.](image)

As it can be seen from Fig.6 and Fig.7, non-preemptive EDF provides considerable performance improvement in terms of DMR. This is because it schedules data transfer requests by considering deadlines of records even it does not suspend ongoing transfer. The round-robin scheduling also satisfies a number of deadline constraints, but this is made unconsciously.

### IV. PERFORMANCE ANALYSIS

Studies on performance issues are conducted by using NS2. As another centralized medium access mechanism, 802.11 PCF, is used to compare it with proposed DSMAC protocol. DSMAC is implemented by making modifications on 802.11 PCF support patch [13] in NS2. Contention period of PCF is deactivated so only centralized contention-free medium access scheme is considered for comparison between PCF and DSMAC. PHY layer parameters are set based upon 802.11b standard. Deadline Meeting Rate (DMR) and Average Waiting Time (AWT) are considered as main performance measures that we employ to measure the performance of DSMAC protocol. All simulation results provided below are average results of 20 experiments. Table III shows general parameters used for wireless node configuration in simulation studies.

![Table III](image)

A. Effects of Average Inter-arrival Time

One of the main factors which effects DMR is inter-arrival times of UAVs to the GS. When real-world conditions are considered, arrivals of UAVs to the GS are completely random and independent from each other. However, when these random occurrences of arrivals are observed long enough, a certain occurrence rate can be obtained. For this reason, random UAV arrivals to the GS are considered as a Poisson process which is widely used random process to model random points in time. In this context, inter-arrival times between UAV arrivals to the GS are produced based on exponential distribution which arise naturally from the Poisson process.

![Table IV](image)

![Fig. 8. Change in DMR with respect to average inter-arrival times.](image)

Simulation result provided in Fig.8 shows how average inter-arrival times effect DMR both for DSMAC and PCF. In this simulation study, a multi-UAV system is considered to be formed by 4 UAVs. Number of records per UAVs are determined as a random integer between 1 and 5. Record sizes are randomly generated between 5 and 10 MB considering that UAVs collect data as 720p (1280x720) video with the length between 30 and 60 seconds. Deadlines for each records are also randomly generated between 1.5 and 5 times of delivery time estimation of corresponding record to the GS. All random generations are based on uniform distribution except random inter-arrival times which are generated based on exponential distribution. Parameters used in this simulation study is provided in Table IV.

![Graph](image)

As can be seen from the Fig.8, there are similar trends for DSMAC and PCF with respect to DMR. DSMAC outperforms PCF for all average inter-arrival times used in the simulation. When it is considered that a UAV in the...
system has 3 records and 7.5 MB each on average, average total transfer time of these records to the GS is calculated approximately as 77 seconds according to parameters used in the simulation. Performance gain obtained for average inter-arrival times which are close to this average value (50, 75, 100) is about 8% on average while more relaxed average inter-arrival times provide performance gain up to 15% as it is shown in Fig.8. For shorter average inter-arrival times, PCF, which do not take record deadlines into account, may complete most parts of the records which have longer deadline early in the process owing to its round-robin based medium access scheduling mechanism. On the other hand, even DSMAC considers record deadlines for medium accesses, it may suffer from convoy effect problem for shorter average inter-arrival times because of its non-preemptive scheduling scheme. For these reasons, the diversity on performance gain for different average inter-arrival times is observed in the simulation.

Another performance measure which is effected from inter-arrival times to the GS is AWT for records. Fig.9 above shows the change in AWT with respect to average inter-arrival times for the same parameter configuration described for the previous simulation. Both DSMAC and PCF have similar trends for AWT. AWT decreases as average inter-arrival time is increased. It is observed that DSMAC has lower values of AWT for all average inter-arrival times used in the simulation. For more frequent arrivals of UAVs, the difference between AWT values for DSMAC and PCF is much more as it can be seen from the Fig.9. This is because of that DSMAC provides non-preemptive medium accesses while PCF provides round-robin based scheduling. When average inter-arrival time is relaxed enough, both protocols converges to their worst-case AWT values and the AWT gain obtained after their convergence is up to 17 seconds approximately.

Parameters used for another simulation study which is conducted to observe how DMR is effected by different UAV arrival periods for multi-UAV systems consisting different number of UAVs are provided in Table V. An arrival period indicates a period of time which all UAVs of a multi-UAV system should arrive. In this context, a certain arrival period provides different average inter-arrival times for different multi-UAV systems. Table VI shows corresponding average inter-arrival times for three different multi-UAV systems used in this simulation.

**TABLE V**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of UAV</td>
<td>4, 8, 12</td>
</tr>
<tr>
<td>Number of Record for each UAV</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>Record Size</td>
<td>[5, 10] MB</td>
</tr>
<tr>
<td>Deadline Range</td>
<td>$(T_x \times 1.5, T_x \times 5)$ s</td>
</tr>
<tr>
<td>Arrival Periods</td>
<td>5, 10, 15, 20 min.</td>
</tr>
</tbody>
</table>

**TABLE VI**

<table>
<thead>
<tr>
<th>Multi-UAV System</th>
<th>Arrival Period (min.)</th>
<th>Average Inter-arrival Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 UAV</td>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>400</td>
</tr>
<tr>
<td>8 UAV</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>171</td>
</tr>
<tr>
<td>12 UAV</td>
<td>5</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>110</td>
</tr>
</tbody>
</table>

In this simulation, three different multi-UAV systems which consist 4, 8, and 12 UAVs are considered to arrive at the GS in 5, 10, 15, and 20 minutes. Simulation result is presented in Fig.10. As it can be understood from the Table VI, for the same arrival period, inter-arrival times for different multi-UAV systems varies because of the number of UAVs they consist. For arrival period of 5 minutes, multi-UAV systems of 4, 8, and 12 UAVs have 100, 42, and 28 seconds average inter-arrival times respectively. Therefore, results obtained for DMR in 5 minutes of arrival period...
show that 4-UAV system has a DMR about 80% while 8-UAV and 12-UAV systems have about 20% and 10% DMR respectively for DSMAC protocol. Also, it is observed that DSMAC outperforms PCF with respect to DMR for all arrival periods used in the simulation. In addition, multi-UAV systems consisting much more UAVs reach their maximum DMR slowly while systems that contain fewer UAVs converges its maximum DMR more quickly because of varying corresponding average inter-arrival times.

B. Effects of Average Record Size on Average Waiting Time

Size of records UAVs have directly effects the AWT performance for both protocols due to its first-hand relation to the transmission time. This simulation study is conducted to show how AWT changes through the average size of records. Simulation configuration is provided in Table VI below.

<table>
<thead>
<tr>
<th>TABLE VII</th>
<th>SIMULATION PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Value(s)</td>
</tr>
<tr>
<td>Number of UAV</td>
<td>4</td>
</tr>
<tr>
<td>Number of Record for each UAV</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>Average Record Size</td>
<td>5, 10, 15, 20 MB</td>
</tr>
<tr>
<td>Deadline Range</td>
<td>[tTx x 1.5, tTx x 5] s</td>
</tr>
<tr>
<td>Average Inter-arrival Time</td>
<td>75 s</td>
</tr>
</tbody>
</table>

As shown in Fig.11, AWT is increased as the average record size is increased. DSMAC outperforms PCF for all average record sizes used in the simulation. This is because DSMAC do not interrupt an ongoing transmission in its operation while PCF performs a preemptive medium access scheme allowing all UAVs arrived at GS to access the medium for short periods by turns.

C. Effects of Delivery Deadline Range on Deadline Meeting Rate

Delivery deadlines for records is another consideration for DMR. The delivery deadline generation range that we use in simulation studies have a great impact on performance of meeting these delay bounds. In simulation studies, deadlines are generated within a certain range using random uniform distribution. Based on the fact that UAVs are assumed to be capable of making delivery time estimation for each record they have, deadlines for each records are randomly generated between 1.5 and \(i\) times of delivery time estimation of corresponding record. The value of \(i\) indicates the maximum boundary of the delivery deadline range. Fig.12 shows the change in DMR with respect to deadline generation range for DSMAC and PCF. Parameters used in this simulation is provided in Table VIII.

TABLE VIII

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of UAV</td>
<td>4</td>
</tr>
<tr>
<td>Number of Record for each UAV</td>
<td>1, 2, 3, 4, 5</td>
</tr>
<tr>
<td>Record Size</td>
<td>[5, 10] MB</td>
</tr>
<tr>
<td>Deadline Range</td>
<td>[tTx x 1.5, tTx x 3, 5, 7, 9] s</td>
</tr>
<tr>
<td>Average Inter-arrival Times</td>
<td>75 s</td>
</tr>
</tbody>
</table>

Here, our aim is to observe DMR performance of DSMAC and PCF by relaxing the deadline range gradually. As shown in Fig.12, both DSMAC and PCF have poor performance results for initial deadline range which is too strict to meet the deadline constraints of records in this simulation configuration. As this range is relaxed by increasing the maximum limit of the range, both protocols have started to produce better results in terms of DMR. This is because the value of average deadline is also increased when the range that we generate random deadlines is relaxed. It is also shown that DSMAC gives better DMR performance results than PCF for all ranges that we choose due to its deadline sensitivity. Although the performance difference between two protocols is much less for too strict deadline ranges, it grows as the range is started to be wider until reaching a certain point. If the maximum boundary of the range is increased too much, it is obvious that both protocols will be capable of meeting deadlines of all records naturally due to high average deadline range obtained in this case.

Fig. 11. Change in AWT with respect to average record size.

Fig. 12. Change in DMR with respect to delivery deadline generation range.
V. CONCLUSION

Research efforts on DTN in the literature mainly focus on data delivery/routing schemes. However, link layer packet collision problem should not be overlooked for DTN based applications, particularly, densely distributed nodes are on subject. Additionally, certain applications may necessitate specific amount of delay tolerance for data delivery rather than completely disregarding it even they perform under DTN model. Based on such DTN-based applications under multi-uav system scenario, Deadline Sensitive Medium Access Control (DSMAC) protocol is presented in this paper.

The DSMAC protocol is a novel medium access solution that seeks to achieve timely data transfer as possible with contention-free and centralized access mechanism. It enables UAVs in a DTN-based multi-UAV system to continue their operation as fast as possible with non-preemptive scheduling executed on channel access function in the GS. To the best of our knowledge, medium access in DTNs has not been studied from this perspective before and this is the first research effort focusing on deadline sensitivity of channel allocation for DTN based multi-uav systems.

To investigate the performance of DSMAC protocol, we have developed an evaluation environment by implementing it on NS2. In addition, DSMAC has been compared to PCF mode of widely used IEEE 802.11 protocol in terms of deadline meeting rate and average waiting time performance measures. Simulation results show that DSMAC protocol provides considerable performance improvements in terms of average waiting time and deadline meeting rate.

REFERENCES

Importance of Business Intelligence Solution on Decision-Making Process of Companies

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Abstract - Nowadays, many companies meet the needs of data from different data sources in different formats in order to line with changing business needs. Data is managed and stored in different parts of the system. Business intelligence is the most effective solution that allows to see big picture by integrating all of the distributed data within a storage. Business intelligence has emerged as a natural result of the previous system designed to support the decision-making process. Over time, visual deficiencies discovered in decision support systems, difficulties of usage and mismatch between applications, is one of the major factors in the rise of business intelligence technology. Such solutions are up to date and integrated view of business performance it offers the greatest benefits to decision makers.

By increasing centralization of data quality, control and scheduling capabilities have allowed us to take quick and right decisions in the evolving competitive environment. The concept of business intelligence is an important element of taking strategic decisions and implementation point in globalized world. This study has designed by Oracle business intelligence tool and results have been a key element of evaluation in decision making processes of the companies.

Keyword – Decision making, business intelligence, big data

I. Introduction

Rapid changes in the business life and complex situations that come along with these changes force businesses to make fast and accurate decisions. This journey started with the use of decision support systems which are being replaced by business intelligence technologies due to changing business needs.

Instead of depending on their personal predictions and intuition, decision makers must adopt approaches based on facts in order for companies to have competitive advantage. With the introduction of business intelligence tools, centralized data sources enhance data quality and control, as well as shortening decision-making and action-taking time by preventing decision makers from getting lost in different data sources. Centralized data sources may sometimes appear in the form of data warehouses and sometimes in the form of data marts containing department- or issue-specific solutions.

The number of studies in Turkey on business intelligence systems, which are recognized more and more by companies for their importance, is insufficient. The purpose of this study is to emphasize the effect of business intelligence solutions used in the finance sector, which has a direct relationship with money, on company strategies and explain their advantages for companies.

II. Strategic Decision-Making

Strategic decisions have long-term and profound impacts. Access to complete and accurate information in line with business needs on time has made decisions more structured. Data warehouses store the data constantly cleaned and updated with ETL (Extract-Transform-Load) processes, which are designed in a planned way, and fulfill the quality data element, which is one of the important factors in the decision-making process. Softwares that allows for the management of the business intelligence process contribute to the decision making process by bringing all the technical work to a level which the decision maker will understand using visual tools such as display panels, pivot tables or graphs.

Decision-making and action-taking occur after the intervention of many factors simultaneously. Considering today’s conditions, competition between companies seem to be getting fiercer with each passing day with emerging technology. To be able to survive in the dynamic business life is not possible with adopting emerging technologies to the company alone. The cornerstone of fast and effective decision-making is to provide analyses designed in accordance with today’s needs to competent decision makers who are able to accurately assess results of these analyses, which provides a considerable competitive advantage for companies.

It has been found in recent studies that most companies cannot use corporate data in decision-making processes efficiently. The amount of collected data increases exponentially with each passing day, which means that the competition between companies increases at the same pace. It is of great importance to have different and well-integrated information sources for an effective decision-making process. At this point, business intelligence is provision of a powerful,
low-cost, easy-to-use and sharable source, which can meet the needs.

The resulting heaps of information with changing technology were not useful to upper management. A need for management information systems allowing for the presentation of integrated and summary data emerged. Decision support systems were developed for this purpose. However, visual inadequacies, usage difficulties and integration problems between applications created the need for a new system to achieve this purpose and established a ground for the introduction of Business Intelligence Systems.

III. Business Intelligence

Business intelligence as a term was used for the first time in 1989 by Howard Dresner, who worked as an analyst and researcher at Gartner Group. Howard Dresner saw business intelligence as a decision support system based on facts and an umbrella covering all methods and ideas that enhance the ability of business-related decision-making.

Humanity’s endless search has been an important driving force in the advance of technology, as in many areas of life. Findings and results obtained from research have been the harbinger of new technologies of future. Business intelligence designs and softwares are a new technology developed in order to overcome deficiencies experienced by companies in relation to support the decision-making process and increase administrative decision-making efficiency, which has began to be used in practice.

Business intelligence application softwares are considered to be the latest point that decision support systems have reached. Therefore, they have a wider scope compared to decision support systems. They contain a higher level of analysis and more estimation algorithms. In addition, offering a powerful visual tool support is one of the important reasons why they are used widely today.

A well-designed technological infrastructure is not enough for a new solution to be adopted widely. To correctly describe and explain the philosophy behind the solution and its meaning is at least as important as the solution itself. Many definitions have been made for business intelligence to emphasize its contribution to the decision-making process and effectiveness of administrative decision-making ([1-6]).

Kraft Foods, which has its head office in Illinois, USA, employs about 125,000, has a annual revenue of USD 110 million with its more than 70 brand, has 40 brands in the market for more than 100 years and has an asset size of USD 49 billion and is the second biggest food company in the world, started to use SAP Business Objects BI 4.0 business intelligence application in 2012. The main purpose of the project was to make it possible to rapidly and effectively reach the rich data in the ERP system of the company through user-friendly interfaces. Mike Walsh, the Business Intelligence Director of Kraft Foods expressed his satisfaction with the installation and implementation by saying, ”These solutions have made everything we do easier”. In addition, improved query performance and more self-serve reporting across the company are other positive outcomes of the project.

Considering success stories with business intelligence softwares, the following are observed ([7.8]):

- It is possible to access the desired data at the desired place through visual graphics comfortably and understandably without needing IT specialists,
- It is possible to access appropriate data among million lines of data in a shorter time and ensure a faster decision-making process,
- The huge amount of time spent for data tabulation and evaluation can be channelized to customers and decision makers,
- A lower number of key performance indicators are used,
- A higher level of report optimization is achieved,
- The simplification of data is much more comfortable.

IV. Experiments

In terms of accounting and financial reporting, the information required by banks for analysis and interpretations such as the following is prepared in a standard way:

- Ensuring uniformity,
- Obtaining uniform balance sheets and income statements directly,
- Obtaining information required for auditing and supervision in a verifiable and auditorable manner,
- Reaching information required by authorities to monitor and direct the economy and other statistical data,
- Financial analysis,
- Risk analysis,
- Efficiency analysis.

Oracle Business Intelligence 11.1.1.7.140527 was used in the implementation of the study. Within the scope of our study, we held meetings with finance group employees in different periods in order to determine business needs both verbally and in written. As a result of these meetings, the study was shaped on a business model covering technical analysis documents and queries that end-users desire and may desire in future.

Database which was used

- Oracle Database 11g Enterprise Edition Release 11.2.0.4.0 - 64bit Production
- PL/SQL Release 11.2.0.4.0 - Production
- CORE 11.2.0.4.0 - Production
- TNS for Linux: Version 11.2.0.4.0 - Production
- NLSRTL Version 11.2.0.4.0 – Production

Fig. 1 shows a screenshot related to one of the steps of creating the physical layer used in the study and Fig. 2 shows a screenshot related to displaying data.
Fig. 1 Creating physical layer tables

Fig. 2 Displaying data

Fig. 3-4-5 show screenshot related a few of the steps of creating the business model and mapping used in the study.

Fig. 3 The current business model and mapping

Fig. 4 Business model and mapping fact table design-2

Fig. 5 Displaying the business model and mapping table relations

Fig. 6 shows a screenshot related to one of the steps of creating the presentation layer used in the study.

Fig. 6. Displaying the presentation layer
Business Intelligence Production

Oracle Business Intelligence web interface is a reporting tool that allows us to reach the data in the system in line with defined targets, perform analyses that make is possible to make healthy decisions and present these with visual richness. Once the Data Mart design, which is the first phase of the study, is completed, we can go on with the next phase, which is providing an Oracle web interface for end-users. This phase which emerges after needs analysis allows end-users to create reports using a drag and drop technology. The relevant screenshot is given in Fig.7.

![Figure 7. Displaying analysis results](image)

V. Conclusion

Reports obtained as a result of the solution designed within the scope of the study allows us to find customer details based on the ledger account number.

The solution, which began to be used by the finance group of the bank, allows us to find customer details based on the ledger account number and evaluate loans given or taken by the bank from a financial perspective. Requested data presents periodic profit and loss information to the bank. It also allows for a cross-check between bottom totals of accounts found on the basis of customer and voucher number and bank balance, which is used a checking tool in accounting. These checks lay the groundwork for preparation of steps that will allow for healthier banking operations by detecting vouchers prepared for the wrong account number. For example, it is possible to make improvements in the current banking software thanks to detection of continuous mistakes. Also, long-term and short-term loan information that banks are obliged to report to the tax office periodically, constitute a resource for decisions related to loans for the government.

ACKNOWLEDGMENT

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REFERENCES

Elevator System. A Case Study of Coloured Petri Nets

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Abstract—A fairly general model of the elevator system is presented. Coloured Petri Nets (CPN) and CPN tools are adopted as modeling tools. The model, which is independent of the number of floors and elevators, covers different stages of the elevator system in substantial detail. The model assists simulation-based analysis of different algorithms and rules which govern real elevator systems, including calculating serving time and waiting time. The results prove the compatibility and applicability of this model in various situations and demonstrate the expressive power and convenience of CPN.


I. INTRODUCTION

Coloured Petri Nets (CPN), first proposed in [7] and later substantially modified and enhanced in [8] and [9], are an extension of Petri Nets (c.f. [13]), and are often used to model behaviours of large variety of complex systems. Nevertheless, the question whether or not CPN are an effective technique for modeling real-world applications of interconnected communicating systems is still of interest for software developers and modelers. In this paper we discuss a CPN model of the elevator system. The elevator system is one of the software engineering benchmarks that are frequently used to test the expressive power, readability and convenience of various formal specification techniques [5].

This paper is an extension and refinement of the results presented in [1], however it can be read independently. The main difference is calculating service time and waiting time.

Various types of Petri nets have been used to model the elevator system before, a detailed list of references can be found in [1], here we mention only [4], [6], [10] and [11].

Nevertheless, all the previous models (except [1]) are either static, or the concept of colour as a data type was not fully utilized, or other formalisms as UML were substantially involved.

The model presented in this paper is independent on the number of floors and elevators, it covers in substantial detail different stages of the elevator system. We believe our model is flexible enough to be adapted to different algorithms and rules, and may eventually evolve in a ‘standard’ formal model of the elevator system.

II. THE ELEVATOR SYSTEM

Elevator systems are an integral aspect of most buildings. Transportation between floors, often with heavy goods, is in many cases almost impossible just by using stairs, especially for high-rise buildings. Quite often multiple elevators are required and such systems are usually very complex. Multiple elevators must be controlled by a centralized control mechanism. The complexity of these elevator systems arises from factors such as scheduling needs, resource allocation, and stochastic control, to name a few. Handling these jobs usually results in systems behaving as discrete event systems [12]. Moreover, the differences among the types of buildings and their traffic patterns also add to the complexity of the elevator systems. For example, elevator passengers in residential, institutional, or commercial buildings might face some mix of popular traffic patterns as: up-peak traffic (also called incoming traffic) where the traffic flows mostly from the first floor to other floors, down-peak traffic (also called outgoing traffic) where the traffic flows mostly to the first floor from other floors, and balanced traffic (also called random traffic) where none of the two previous patterns dominates [2], [14].

The elevator system is usually defined as follows [5]: An elevator system is to be installed in a building with m floors and n cars. The elevator and the control mechanisms are supplied by the manufacturer. The internal mechanism of an elevator system is assumed (given). The problem concerns the logistics of moving cars between floors according to the following constraints:

• Each elevator’s car has a set of buttons - one for each floor. These buttons illuminate when pressed and signal the elevator to move to the corresponding floor. The illumination is canceled when the corresponding floor is visited by the car.

• On the wall outside the elevator each floor has two buttons (with the exception of the ground and the top floors). One button is pressed to request an upward moving elevator and another button is pressed to request a downward moving elevator. If both buttons are pressed, then each direction is assigned to a different car. These buttons illuminate when pressed. The illumination is canceled when the assigned car visits the floor.

• When an elevator has not received any requests for service, it should be held at its parking floor with its doors closed until it receives further requests.
• All requests for elevators from floors (i.e. hall calls) must be serviced eventually. The applied algorithm controls the priority of floors. 
• All requests for floors within elevators (i.e. car calls) must be serviced eventually, with floors usually serviced sequentially in the direction of travel. 
• Each elevator’s car has an emergency button which when pressed causes a warning signal that is sent to the site manager. The car is then deemed “out of service”. Each car has a mechanism to cancel its “out of service” status. 

### III. COLOURED PETRI NETS

Coloured Petri Nets are a discrete-event modelling language combining the capabilities of Petri Nets with the capabilities of a high-level programming language. Petri Nets provide the foundation of the graphical notation and the basic primitives for modeling concurrency, communication, and synchronization. Coloured Petri Nets allow tokens to have a data value attached to them. This attached data value is called token colour. Coloured Petri Nets allow tokens to have a data value attached and to be used to model concurrency, communication, and synchronization.

A semi-formal definition can be given as follows: A Coloured Petri Net is a tuple:

\[ N = (P, T, A, \Sigma, C, N, E, G, I) \]

where:

- \( P \) is a set of places and \( T \) is a set of transitions.
- \( A \) is a set of arcs and \( P \cap T = P \cap A = T \cap A = \emptyset \).
- \( \Sigma \) is a set of colour sets defined within CPN model. This set contains all possible colour, operations, and functions used within CPN.
- \( C \) is a colour function which maps places in \( P \) into a colour in \( \Sigma \).
- \( N \) is a node function which maps \( A \) into \( (P \times T) \cup (T \times P) \).
- \( E \) is an arc expression function which maps each arc \( a \in A \) into the expression \( e \). The input and output types of arc expressions correspond to the type of nodes which the arc is connected to.
- \( G \) is a guard function which maps each transition \( t \in T \) into guard expression \( g \). The output of the guard expression should evaluate to Boolean value \textit{true} or \textit{false}.
- \( I \) is an initialization function which maps each place \( p \) into an initialization expression \( i \). The initialization expression must evaluate to a multiset of tokens with a colour corresponding to the colour of the place \( C(p) \).

CPN support hierarchical modeling and are equipped with a modeling language called CPN ML which is based on the standard functional programming language ML. There are a variety of tools that can be used. In this paper the tools from [3] have been used. For more details and theory of CPN, the reader is referred to [9].

Throughout this paper we will use \( \mathbb{R} \) (\( \mathbb{R}^+ \)) to denote \textit{Reals} (non-negative \textit{Reals}), \( \mathbb{Z} \) (\( \mathbb{Z}^+ \)) to denote \textit{Integers} (non-negative \textit{Integers}), \( [x_1, \ldots, x_n] \) to denote the list \( x_1, \ldots, x_n \), and \( \text{lists}(X) \) to denote finite lists built from the elements of \( X \).

### IV. CPN-BASED MODELLING OF ELEVATOR SYSTEM

Our model of the elevator system consists of four major interconnected but independent sub-models, namely: \textit{timing car-structure}, \textit{timing hall-call}, \textit{timing car-call}, and \textit{timing system-cycle}.

Their functions and interconnections are described as follows. The timing car-structure sub-model represents the elevator’s cars. It is at the centre of all other sub-models that concurrently control the elevator’s cars. Typically, an elevator car is requested by either a hall-call or a car-call. A hall-call is placed by pressing a button located in the hallway of a given floor while a car-call is placed by pressing a button inside the car of the elevator. When a hall-call is placed, the timing hall-call sub-model will assign the hall-call to the appropriate car of the timing car-structure sub-model (details depend on the algorithms that are used). Similarly, the timing car-call sub-model coordinates the placed car-calls with the cars of the timing car-structure sub-model. Finally, the timing system-cycle sub-model operates the cars of the timing car-structure sub-model to service the requested calls.

#### A. Timing Car-Structure

The timing car-structure sub-model (Figure 1) is composed of two places: Timing Cars and Timing Database, that also belong to other sub-models. The Timing Cars place is a Cartesian product defined in Table I. The Timing Database place, defined in Table II, is just a list of cars’ states data. Hence, both places are initialized dynamically by the functions \textit{initialize cars} and \textit{initialize database} respectively (see Figure 1).

![Fig. 1: The timing car-structure sub-model](image)
hall calls are used to transfer the tokens of assigned hall calls from the timing hall-call sub-model to the timing system-cycle sub-model. The other elements of the colour set Timing Cars are rather self-explanatory.

**TABLE I**

THE COLOUR SET TIMING CARS

<table>
<thead>
<tr>
<th>Colour Sets</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car ID</td>
<td>{i \mid i \in \mathbb{Z}, 1 \leq i \leq \text{total number of cars}}</td>
</tr>
<tr>
<td>Range</td>
<td>{x \mid x \in \mathbb{Z}, \text{lowest floor} \leq x \leq \text{highest floor}}</td>
</tr>
<tr>
<td>Status</td>
<td>{up, down, emergency, idle, out of service}</td>
</tr>
<tr>
<td>Desired Floors</td>
<td>{[l_1, \ldots, l_k] \mid k \in \text{Range}}</td>
</tr>
<tr>
<td>Call Issuer</td>
<td>{request, system, non, reservation}</td>
</tr>
<tr>
<td>Timing Hall Call</td>
<td>{(\text{hall call, direction, time}) \mid \text{hall call} \in \text{Range}, \text{direction} \in \text{Status}, \text{time} \in \mathbb{R}}</td>
</tr>
<tr>
<td>Timing Hall Calls</td>
<td>{[h_1, \ldots, h_k] \mid h_i \in \text{Timing Hall Call}}</td>
</tr>
<tr>
<td>Timing Cars</td>
<td>{(\text{car id, current floor, status, parking floor, desired floors, call issuer, stops limitation, time period, served hall calls}) \mid \text{car id} \in \text{Car ID}, \text{current floor} \in \text{Range, status} \in \text{Status, parking floor} \in \text{Range, desired floors} \in \text{Desired Floors}, \text{call issuer} \in \text{Call Issuer, stops limitation} \in \mathbb{Z}, \text{time period} \in \mathbb{R}, \text{served hall calls} \in \text{Timing Hall Calls}}</td>
</tr>
</tbody>
</table>

**TABLE II**

THE COLOUR SETS TIMING DATABASE

<table>
<thead>
<tr>
<th>Colour Sets</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing Car’s Data</td>
<td>{(\text{current floor, status, destinations, car id, time}) \mid \text{current floor} \in \text{Range, status} \in \text{Status, destinations} \in \text{Desired Floors, car id} \in \text{Car ID, time} \in \mathbb{R}}</td>
</tr>
<tr>
<td>Timing Database</td>
<td>{[g_1, \ldots, g_k] \mid g_i \in \text{Timing Car’s Data}}</td>
</tr>
</tbody>
</table>

**TABLE III**

THE COLOUR SET HALL BUTTONS

<table>
<thead>
<tr>
<th>Colour Sets</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall Call</td>
<td>{(\text{hall call floor, status}) \mid \text{hall call floor} \in \text{Range, status} \in \text{Status}}</td>
</tr>
<tr>
<td>Hall Calls</td>
<td>{[h_1, \ldots, h_l] \mid h_i \in \text{Hall Call}}</td>
</tr>
<tr>
<td>Hall Buttons</td>
<td>{[\text{IB, USB, UUB}] \mid \text{IB} \in \text{Hall Calls, USB} \in \text{Hall Calls, UUB} \in \text{Hall Calls}}</td>
</tr>
</tbody>
</table>

**B. Timing Hall-call**

This sub-model executes an algorithm, giving by the user, that assigns a hall-call to the most appropriate car. It also can generate hall-calls from arbitrary floors, selected floors, or both.

Invoking hall calls, which involves button illuminations, starts from place Hall Buttons, which contains a single token from the colour set defined in Table III. In principle, it is a list of triples (IB, USB, UUB), where IB - illuminated buttons (IB), USB - unilluminated-specified buttons, and UUB - unilluminated-unspecified buttons, are also (internal) lists.

Invocation of a Hall Call requires the firing of transition Release Hall Call. This transition is enabled if and only if the following conditions are satisfied:

1) At least one of USB or UUB is not empty,
2) If the limit of producing calls is finite, then it has not been already reached,
3) The number of produced calls is less than the value of parameter pause number (see Table IV).

The condition (3) guarantees the balance between the producing process and the assignment process.

After firing the transition Release Hall Call, an appropriate tuple from either the USB list or the UUB list is removed and placed into both the IB list and place Requested Hall Call. The choice between the USB list and UUB list is based on the following rules:

1) When one list is empty, the other list is always selected.
2) The difference between both lengths of lists is less or equal to the value of parameter frequency of most requested floors.
3) The internal choice between tuples is sequential for USB list and arbitrary (non-deterministic) for UUB list.

The waiting time is calculated in three steps. First, when a hall call is released from place Hall Buttons and put in place Requested Hall Call, the current times of all cars become attached to this hall call (see Table V). Second, when the placed hall call is assigned to a car, it is removed from place Requested Hall Call and the lists: desired-floors and served-hall-calls (see Table I) are appropriately modified.

Third, when the assigned car arrives at the floor of the placed hall call, then the waiting time is calculated as the absolute value of the difference between the time of the car’s arrival and the registered time when the hall call was released. For more details and particular algorithms, the reader is referred to [1].

Fig. 2: The timing hall-call sub-model
The parameters of the timing hall-call sub-model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Legal values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Producing mode</td>
<td>{ finite, infinite }</td>
</tr>
<tr>
<td>Times of finite hall calls</td>
<td>{ y</td>
</tr>
<tr>
<td>Most requested floors</td>
<td>{ hci, \ldots, hce</td>
</tr>
<tr>
<td>Frequency of most requested floors</td>
<td>{ d</td>
</tr>
<tr>
<td>Algorithms for assigning hall calls</td>
<td>{ minimum waiting, nearest, scope }</td>
</tr>
<tr>
<td>Travel time</td>
<td>{ t</td>
</tr>
<tr>
<td>Average stop times</td>
<td>{ s</td>
</tr>
<tr>
<td>Production pause number</td>
<td>{ p</td>
</tr>
</tbody>
</table>

The transition Place Car Call is enabled if and only if the following conditions are satisfied:
1) At least one of the lists UUCB and USCB is not empty,
2) The selected car has not reached its maximum number of accepted calls,
3) If the limit of producing calls is finite, then it has not been reached yet.

A selected algorithm in Timing Hall-call sub-model may also affect car calls process. Firing the transition Place Car Call modifies two lists: most-desired floors (see Table VII) and illuminated car buttons (ICB), by placing appropriate floor number in both of them respectively.

<table>
<thead>
<tr>
<th>Colour Sets</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car Time</td>
<td>{ (car id, time)</td>
</tr>
<tr>
<td>Cars Times</td>
<td>{ [c_1, \ldots, c_n]</td>
</tr>
<tr>
<td>Requested Hall Call</td>
<td>{ (hall call, waiting times) \land hall call ∈ Hall Call, waiting times ∈ Cars Times }</td>
</tr>
<tr>
<td>Coordinator</td>
<td>{ (specified call, unspecified call, next selection, released calls)</td>
</tr>
</tbody>
</table>

D. Timing System-cycle
The Timing System-cycle (Figure 4) models three stages: maintenance, arrival, and transition, of cars operations. In addition, it makes a simulation-based analysis possible.
At the arrival stage, when a car reached its desired destination, transition Arrival fires and the time of a delivered call is calculated and logged. If the delivered call was a hall call then the waiting time is the absolute value of the difference between the arrival time of the car and the registered time when the hall call was placed. The calculated result is stored in place Hall Call LOG (see Table VIII for an appropriate colour sets).

Similarly, the serving time of a delivered car call is the absolute value of the difference between the arrival time of the car and the registered time when the car call was placed (see the timing car-call sub-model). The result is stored in place Car Call LOG (c.f. Table VIII). The type of a delivered call (i.e. whether it is a hall call, a car call, or both) is determined by checking simultaneously the illuminated-car-buttons list of a place Car’s Buttons, the illuminated-buttons list of place Hall’s

![Fig. 3: The timing car-call sub-model](image-url)
Buttons, and the served-hall-calls of place Timing Cars. Moreover, each delivered hall call or car call is returned to its original list after it was removed from the illuminated-buttons list or illuminated-car-buttons list, respectively. The doors operations are represented by the colour set Doors (c.f. Table VIII).

![Diagram](image_url)

**Fig. 4:** The timing system-cycle sub-model

In the maintenance stage, when a car is suspended either by an emergency case (i.e. emergency button was pressed) or an operation failure case, the transition Maintain, which has the highest priority of firing upon enabling in the entire model, is fired. In such case the pending car’s token is transferred temporarily to place out of service, which is not accessible by any other sub-models, all assigned hall calls and car calls of the pending car are returned to places Hall’s Buttons and Car’s Buttons, respectively, and a warning message is sent to the site manager, which is denoted by place warning to manager. A suspended car may be restarted, either automatically or manually based on the value of parameter restart cars automatically that controls the enabling of transition Restart.

Cars movements between floors are modeled in the transition stage. Transitions Transfer and Maintain are mutually exclusive. Enabling and firing the transition Transfer requires that the car desired-floors list is not empty, and the car current floor matches no calls of the desired-floors list. After firing transition Transfer, the car token is updated in the following way. If the car desired-floor list has calls beyond the car current floor, it continues moving in the same direction. Otherwise its direction is reversed. In both cases, the token in place Database is updated accordingly.

Once a car reached its desired destination, it is in the arrival stage. At this stage, transition Arrive is enabled provided that transition Maintain is disabled and the car current floor matches a requested call from the desired-floors list. After firing transition Arrive, car’s token is updated by dropping the requested floor from the car desired-floor list. Additionally, the car state is set to one of three cases. If the car desired-floor list

<table>
<thead>
<tr>
<th>Colour Sets</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Doors</strong></td>
<td>(car id, current delivery number, deliveries’ total)</td>
</tr>
<tr>
<td><strong>Hall Call LOG</strong></td>
<td>([hall call, waiting time])</td>
</tr>
<tr>
<td><strong>Serving times</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Car Call LOG</strong></td>
<td>([car id, serving time])</td>
</tr>
<tr>
<td><strong>Restart cars automatically</strong></td>
<td></td>
</tr>
</tbody>
</table>
has more calls, then it continues serving the requested calls. Otherwise, the car is set to idle, if the car current floor agrees with its parking floor, or alternatively, the car is dispatched to its parking floor with an appropriate direction.

V. ANALYSIS

CPN models can be analyzed and evaluated by various techniques and tools [15]. In this paper, we used the simulation-based performance analysis using tools from [3], with various parameters including numbers of cars and floors, types of decision algorithms, specified floors, etc. The results of our simulation-based performance analysis has proved validity and applicability of our model in various situations.

Due to page limit, we mention only one case study: five cars serving a twenty-floor building. Among others, we obtained the following results.

1) Car calls were produced by timing car-call sub-model for each car to each floor. Additionally, the car-call buttons were illuminated when released and unilluminated when the cars visited the corresponding floors.

2) Hall calls were produced by timing hall-call sub-model from all floors to request cars. Additionally, the hall-call buttons were illuminated when released and unilluminated when the cars visited the floors of the requested hall calls.

3) All requested hall calls were eventually served for all algorithms used.

4) All requested car calls were served eventually and sequentially in the direction of car movements.

5) If no calls, all cars were held at their parking floors.

6) The maintenance stage worked as it supposed to.

The results of two particular experiments are presented in Figure 5.

VI. CONCLUSION

In this paper, a fairly general CPN-based model of the elevator system, one of specification benchmarks [5], is proposed. The model consists of four separated but interconnected parts and it emphasis the expressive power and convenience of Coloured Petri Nets. Our model is quite flexible and it allows using different algorithms and different rules at ease. Division into four sub-models allows easy tracking of errors and faults. A thorough simulation-based performance analysis by using the simulator provided in [3].

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REFERENCES

APPLICATION OF FUZZY LOGIC IN LAND CONSOLIDATION-CLASSIFICATION STUDIES

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Abstract—Land classification is one of the most important stages of consolidation projects. The success and timely completion of this project depends on that this classification is useful and fair and are accepted by landowners. Different methods have been developed for the classification. Effects on the success of the land consolidation of the results of these methods are being investigated.

In this study, fuzzy logic method has been used for land classification according to Law No. 5403. In Mamdani Type Fuzzy Logic, Values of soil index, productivity index and the location index, which are used to determine the value of the parcel index, have been defined as input, whereas the value of parcel index have been defined as the output. Inputs and outputs have been converted to the linguistic terms (such as very efficient, inefficient, somewhat efficient, remote, near) by creating membership functions. Rule base has been created for calculating of the parcel index. As a result of fuzzy inference and defuzzification process, the model formed by Mamdani Type Fuzzy Logic gives the value of parcel index. By giving random input values to test generated model, results has been compared with results obtained manually.

Keywords—fuzzy logic, land consolidation, land classification, fuzzy systems, soft computing

I. INTRODUCTION

Land consolidation studies have a set of technical services in order to increase productivity in agriculture regulating agricultural space along with a variety of infrastructure services (road-irrigation network, drainage, soil leveling, construction of village settlements etc.) [1].

To give lands equal to their previous lands to landowners after the consolidation process in land consolidation area, classification process based on specific criteria of their existing plots must be made [2].

Land classification according to Soil Conservation and Land Use Law (Law No. 5403) has been defined as values found based on soil and productivity etudes and been basis to the change of land with soil's natural and permanent features and the distance to settlement or business center of land. The aim of classification is obtained according to certain criteria of the previous value from land consolidation of lands belonging to businesses.

Land classification, which is the process to estimate the ability of the land yield, includes studies relied that the soil, topography and other features of the land are interpreted and carried out in order to make comparisons between certain forms of evaluation [2].

Land classification is one of the most important stages of consolidation projects. The success and timely completion of this project depends on that this classification is useful and fair and are accepted by landowners. In order to classify lands in many countries of the world, various methods have been developed and have been put into practice [2].

Values of soil index, productivity index and location index is determined when the classification maps for land consolidation are generated, 70% of the index obtained the results of the soil etudes (TE) is taken. By adding the index scores determined for productivity (VE) and location (KE) to this value, value of parcel index is determined. Obtained values of parcel index are evaluated in particular group ranges, and thus, map of classification is formed.

Classifications of parcels according to determined the parcel index are made according to Table 1.

Parcel index (PE) = TE*70% + V + k

<table>
<thead>
<tr>
<th>Classification</th>
<th>Parcel Index</th>
<th>Classification</th>
<th>Parcel Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>91-100</td>
<td>6</td>
<td>41-50</td>
</tr>
<tr>
<td>2</td>
<td>81-90</td>
<td>7</td>
<td>31-40</td>
</tr>
<tr>
<td>3</td>
<td>71-80</td>
<td>8</td>
<td>21-30</td>
</tr>
<tr>
<td>4</td>
<td>61-70</td>
<td>9</td>
<td>11-20</td>
</tr>
<tr>
<td>5</td>
<td>51-60</td>
<td>10</td>
<td>0-10</td>
</tr>
</tbody>
</table>

Discovered fuzzy sets, logic and system concepts by Zadeh in 1965 have occured the result that much nonlinear equations are used, method is complicated and solution becomes difficult in order to working of this researcher for many years in the control area and obtaining the control he wants [3].
The concept of fuzzy logic generally tries to modelling the thinking style of people. It is communicable that turbidity signify the tentative information as a concept, in other words uncertainty. Fuzzy logic is defined as an artificial intelligence technique which run with uncertainties instead of certainties by using verbal variables. Typical value of the verbal variable is expressed with words, such as "hot" or "cold", also, these values are represented by membership functions of fuzzy sets.

The difference from standart mathematical methods of fuzzy logic is runnig with uncertainties instead of certainties and allowing the qualitative definition. That uncertainties are expressed mathematically is evaluated as the greatest convenience which is brought by fuzzy logic the modeling of complex systems [4].

In classical set theory, any object is a member of a cluster or not. This object only has the value of “0” or “1”. The medium of these values is not possible. In fuzzy logic unlike classical logic, members belong to partially the fuzzy cluster and is used in values between '0' and '1'. In the following Figure 1, the difference of binary (classical) logic and fuzzy logic is schematically shown. In Figure 1 it is shown that intermediate values do not exist in classical logic.

The processes of fuzzy logic consists of stages which the problem is analyzed and is defined, sets and logical relationships are formed, available information is converted into fuzzy sets and model is interpreted. By using a lot of prerequisites, it can be decided whether fuzzy logic solves the problem or not. Originally for the problem to be solved, it is decided whether fuzzy logic approach is the right choice or not. If the system's behavior to be applied can be expressed with rules or it requires a complex mathematical operation, fuzzy logic approach can be applied. Otherwise, The results obtained by the fuzzy logic will not give the desired values most likely [5].

![Fig. 1 Representation of the difference between fuzzy logic (a) and classical logic (b)](image)

Fig. 1 Representation of the difference between fuzzy logic (a) and classical logic (b)

![Fig. 2 Blurring defuzzification fuzzy system with unit](image)

Fig. 2 Blurring defuzzification fuzzy system with unit

1) **General Information Base Unit:** It contains the input variables which are affected of event which will be examined and all informations about these. The reason which it is called as the general data base is numerical and / or verbal of the informations here.

2) **Fuzzifier:** This is a processor that assigns to membership degrees in fuzzy sets that has been described as verbal to the digital input values.

3) **Fuzzy Rule Base Unit:** This includes all of rules that connect to output variables to inputs in the database and that can be written in logical IF – IF type. While these rules are written, all intermediate (fuzzy set) connections which may be only between input datas and outputs is considered. Thus, each rule logically connects to the output space to a part of the input space. All of this contexts creates a rule base.

4) **Fuzzy Inference Engine Unit:** This is a mechanism that contains processes community that provide that the system behaves with output by collecting together all of the piece relationship established between the input fuzzy sets and the output fuzzy sets. This engine benefits that How to give an output under inputs of whole system is determined by huddling together the implications of each rule.

5) **Defuzzifier:** This converts to sharp digital output values to results of fuzzy inference obtained result of fuzzy processes.

6) **Output Unit:** This unit specifies community of the output values obtained by the interaction by means of fuzzy inference engine of information and fuzzy rule bases [6].

In this study, fuzzy logic method has been used for land classification according to Law No. 5403. In Mamdani Type Fuzzy Logic, Values of soil index, productivity index and the location index, which are used to determine the value of the parcel index, have been defined as input, whereas the value of parcel index have been defined as the output. Inputs and outputs have been converted to the linguistic terms (such as very efficient, inefficient, somewhat efficient, remote, near) by creating membership functions. Rule base has been created for calculating of the parcel index. In order to benefit from fuzzy informations obtained, this informations have to be defuzzification. Centroid method has been used as defuzzification method. As a result of fuzzy inference and defuzzification process, the model formed by Mamdani Type Fuzzy Logic gives the value of parcel index. By giving random input values to test generated model, results has been compared with results obtained manually.

II. MATERIALS AND METHODS

While fuzzy system is established, the soil index (TE), the productivity index (VE) and the location index (KE) has been defined as the input values of system, whereas, parcel index (PE) has been defined as the output value of system. The general structure of the fuzzy model is shown in Figure 3.

Firstly, while fuzzy model is created, it must be determined that values of soil index, productivity index and location index will be divided how many sub-regions and that what kind of membership function (such as triangular, trapezoidal, Gaussian...).
curve etc.) will be used. In this study, the seven sub-regions for soil index, the five sub-regions for productivity index and the four sub-regions for location index have been determined and triangular membership function has been used.

![Fig. 3 The general structure of Fuzzy Logic Model](image)

**A. Membership Function**

While the fuzzy model is established, different membership functions have been formed for soil index (TE), productivity index (VE) and location index (KE). The membership functions for input and output variables are shown in Figure 4, 5, 6 and 7. Units of factors used are: TE (unit), VE (unit), KE (unit) and PE (unit). TE membership function is in the range of 0-100, VE membership function is in the range of 0-10, LI membership function is in the range of 0-20 and PE membership function is in the range of 0-100.

That the factors used are blurred are carried out with help of the following functions determined by benefiting from an expert's opinions and informations.

- **TE (A)** = \{a; 0<a<100\}
- **VE (B)** = \{b; 0<b<10\}
- **KE (C)** = \{c; 0<c<20\}
- **PE (D)** = \{d; 0<d<100\}

![Fig. 4 The membership function of soil index (TE)](image)

![Fig. 5 The membership function of productivity index (VE)](image)

![Fig. 6 The membership function of location index (KE)](image)

![Fig. 7 The membership function of parcel index (PE)](image)

Such as, The mathematical representation of each membership function of the location index (KE) is as follows:

\[
\mu_{far} (C) = \begin{cases} 
\frac{5-a}{5} & ; 0 < a < 5 \\
0 & ; \text{in different conditions}
\end{cases}
\]

\[
\mu_{near} (C) = \begin{cases} 
0 & ; a \leq 3.5 \\
\frac{1.5}{a-3.5} & ; 3.5 < a \leq 5 \\
\frac{4}{10-a} & ; 6 < a < 10 \\
0 & ; a > 10
\end{cases}
\]

\[
\mu_{the \ nearest} (C) = \begin{cases} 
0 & ; a \leq 10 \\
\frac{1.52}{10-a} & ; 10 < a \leq 12 \\
\frac{6}{12-a} & ; 12 < a < 18 \\
0 & ; a \geq 12
\end{cases}
\]

\[
\mu_{the \ nearest} (C) = \begin{cases} 
\frac{17-a}{3} & ; 17 < a < 20 \\
0 & ; \text{in different conditions}
\end{cases}
\]
B. Rule Base

An appropriate rule base is required for fuzzy logic system. The total of 140 rules have been written for fuzzy system in this study. The portion of them is seen in Table 2. The relationship with parcel index (PE) that is the output value of soil index (TE), location index (KE) and productivity index (VE) that are input values are shown in Figure 8, 9 and 10.

![Fig. 8. The relationship with PE of KE and TE](image)

<table>
<thead>
<tr>
<th>Rule Number</th>
<th>TE</th>
<th>VE</th>
<th>KE</th>
<th>PE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule 1</td>
<td>very inefficient</td>
<td>inefficient</td>
<td>far</td>
<td>too inefficient</td>
</tr>
<tr>
<td>Rule 2</td>
<td>very inefficient</td>
<td>inefficient</td>
<td>near</td>
<td>too inefficient</td>
</tr>
<tr>
<td>Rule 3</td>
<td>very inefficient</td>
<td>inefficient</td>
<td>very near</td>
<td>very inefficient</td>
</tr>
<tr>
<td>…</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule 48</td>
<td>inefficient</td>
<td>somewhat efficient</td>
<td>too near</td>
<td>efficient</td>
</tr>
<tr>
<td>Rule 49</td>
<td>inefficient</td>
<td>efficient</td>
<td>far</td>
<td>inefficient</td>
</tr>
<tr>
<td>Rule 50</td>
<td>inefficient</td>
<td>efficient</td>
<td>near</td>
<td>somewhat efficient</td>
</tr>
<tr>
<td>…</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule 85</td>
<td>efficient</td>
<td>somewhat efficient</td>
<td>far</td>
<td>somewhat efficient</td>
</tr>
<tr>
<td>Rule 86</td>
<td>efficient</td>
<td>somewhat efficient</td>
<td>near</td>
<td>very efficient</td>
</tr>
<tr>
<td>Rule 87</td>
<td>too efficient</td>
<td>inefficient</td>
<td>very near</td>
<td>very efficient</td>
</tr>
<tr>
<td>…</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule 118</td>
<td>too efficient</td>
<td>inefficient</td>
<td>near</td>
<td>very efficient</td>
</tr>
<tr>
<td>Rule 119</td>
<td>too efficient</td>
<td>inefficient</td>
<td>very near</td>
<td>too efficient</td>
</tr>
<tr>
<td>Rule 120</td>
<td>too efficient</td>
<td>inefficient</td>
<td>too near</td>
<td>too efficient</td>
</tr>
</tbody>
</table>

![Fig. 9. The relationship with PE of TE and VE](image)

![Fig. 10. The relationship with PE of VE and KE](image)

III. CONCLUSION

The method developed in this study has been applied the first time for the land classification, according to Land Law No. 5403. As shown in Table 3, the results of Fuzzy Logic Model are compared with results of traditional method. It is seen in Table 3 that both the results obtained from the fuzzy logic model and the results obtained from the traditional method are similar one another. The system is fast and is more accurate than traditional methods. This system also has a high reliability. Besides, accuracy of established fuzzy system has been shown on stabilizing right graph that its angle is 45 degrees (Figure 11).

![Fig. 11. Stabilizing right graph with angle 45 degrees](image)
TABLE III Comparison of the results of Traditional Method and Fuzzy System

<table>
<thead>
<tr>
<th>TE</th>
<th>V</th>
<th>K</th>
<th>PE According to the Traditional Method</th>
<th>PE According to the Fuzzy Logic System</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>9</td>
<td>18</td>
<td>85</td>
<td>90</td>
</tr>
<tr>
<td>74</td>
<td>8</td>
<td>15</td>
<td>75</td>
<td>73.2</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
<td>8</td>
<td>55</td>
<td>59.5</td>
</tr>
<tr>
<td>71</td>
<td>7</td>
<td>13</td>
<td>70</td>
<td>70.2</td>
</tr>
<tr>
<td>55</td>
<td>8</td>
<td>17</td>
<td>63.5</td>
<td>67.4</td>
</tr>
<tr>
<td>95</td>
<td>9</td>
<td>12</td>
<td>87.5</td>
<td>90</td>
</tr>
<tr>
<td>80</td>
<td>5</td>
<td>14</td>
<td>75</td>
<td>79</td>
</tr>
<tr>
<td>78</td>
<td>6</td>
<td>12</td>
<td>73</td>
<td>77.7</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>3</td>
<td>12</td>
<td>13.6</td>
</tr>
<tr>
<td>50</td>
<td>5</td>
<td>10</td>
<td>50</td>
<td>53.5</td>
</tr>
<tr>
<td>61</td>
<td>4</td>
<td>7</td>
<td>53.7</td>
<td>52.8</td>
</tr>
<tr>
<td>40</td>
<td>3</td>
<td>11</td>
<td>42</td>
<td>47.4</td>
</tr>
<tr>
<td>15</td>
<td>3</td>
<td>4</td>
<td>17.5</td>
<td>17.6</td>
</tr>
<tr>
<td>30</td>
<td>2</td>
<td>6</td>
<td>29</td>
<td>23.6</td>
</tr>
<tr>
<td>23</td>
<td>6</td>
<td>4</td>
<td>26.1</td>
<td>23.5</td>
</tr>
<tr>
<td>78</td>
<td>7</td>
<td>10</td>
<td>71.6</td>
<td>73.4</td>
</tr>
</tbody>
</table>

Fig. 11 Accuracy of Fuzzy Logic Model with the help of 45 degrees right

As a result of this study, it is understood that Mamdani Fuzzy Logic Method can be used for the land classification. This system can be further improved by being increased linguistic variables and the number of rules of generated Fuzzy Model.

REFERENCES


Simulation and Analyses of Heterogeneous WSN Clustering Protocols

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Abstract — Limited battery supply of a sensor node is one of the most important factors that limit the lifetime of the WSNs. As a consequence, prolonging the lifetime of WSNs through energy efficient mechanisms has become a challenging research area. Previous studies have shown that instead of implementing direct transmission or multi-hop routing, clustering is a kind of key technique used to reduce energy consumption. Clustering can increase the scalability, decrease the energy consumption and extend the lifetime of the network. Also, energy-efficient clustering protocols have been designed for the characteristic of heterogeneous wireless sensor networks to obtain additional energy savings. In heterogeneous wireless sensor networks, some of sensor nodes is equipped with additional energy resources. In this paper, comparison of stable election protocol (SEP), distributed energy-efficient clustering (DEEC) scheme with LEACH which has also advanced nodes is aimed. Same simulation parameters are used for comparison. The nodes in all heterogeneous algorithms are equipped with same total energy. The protocols are compared in terms of number of alive nodes, lifetime and energy-efficiency in MATLAB. The results of the simulations are discussed in details.

Keywords— Energy Efficient Routing, Clustering, Wireless Sensor Networks.

I. INTRODUCTION

A WSN is obviously formed by a collection of sensor nodes and corresponding protocols for routing messages in this network. A typical wireless sensor node consists of a sensory unit, a communication unit, a power unit and a processing unit. Sensory unit consists of a data acquisition component and ADC (converts the sensed real world data to the digital form). Communication unit has a radio transceiver and the power is backed by a battery source. The WSN node can be equipped with a limited power source (0.5 Ah, 1.2 V). The node remains active as long as the battery is alive and hence power saving is a crucial criterion in this domain of applications. Energy consumption happens in three domains: sensing, data processing and communications. The sensing, signal processing parts operate at low sequential and consume less than 1mW. This is over an order of extent less than the energy consumption of the communication part. Therefore we have to assign less communication/data exchange between sensor nodes.

The traditional infrastructure based protocols cannot be used for WSNs because of the limited storage and power of the sensor nodes. Because WSNs often use broadcast based radio communication.

Limited energy availability in sensor nodes makes network lifetime an important issue in WSN applications. To extend the network lifetime, energy efficient wireless sensor network protocols and algorithms have been devised in the literature. Node clustering, in-network data processing, data fusion and network coding are some of the measures taken to reduce the amount of data that is processed, sensed or transmitted. Minimization of energy spent in processing, sensing and transmission of data allows sensor nodes to save energy. Such energy savings help to extend the lifetime of WSN applications.

The main goal of cluster-based routing protocol is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a cluster and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink and transmission distance of sensor nodes.

There are two kinds of clustering schemes. The clustering algorithms applied in homogeneous networks are called homogeneous schemes, and the clustering algorithms applied in heterogeneous networks are referred to as heterogeneous clustering schemes. It is difficult to devise an energy-efficient heterogeneous clustering scheme due to the complicated energy configure and network operation. Thus most of the current clustering algorithms are homogeneous schemes, such as low energy adaptive clustering hierarchy (LEACH) [1] and their variants [2].

The most successful heterogeneous clustering protocols are stable election protocol (SEP) [3] and distributed energy-efficient clustering scheme (DEEC) [4].

LEACH is one of the most popular distributed cluster-based routing protocols in WSNs. LEACH randomly selects a few nodes as CHs which aggregate data arriving from nodes and forward the aggregated data to BS and rotates this role to balance the energy consumption of the sensor nodes in the network.

In LEACH protocol, the time is divided into parts called a round. Each round consists of two phases. The first phase is setup phase which is the phase of node formation. The second phase is related to the normal function of the network and is called the Steady-State phase. In the first phase, the CHs are elected based on a probability function. This election is as follows: each sensor node selects itself to be CH at any given time with a certain probability. Any node in the network
chooses a random number between 0 and 1. Then this number is compared with threshold limit, if the number is less than a threshold, the node becomes a CH for the current round. This probability function is designed in such a way that within a specific number of rounds each sensor becomes a CH only once and thus the energy consumption is distributed over the whole network. After the set up phase of the round, where the CHs are elected, each CH announces its election to other nodes and each node chooses a suitable (nearest) CH for itself; and then it announces this decision to the related CH and thus the clusters are formed and the network comes into the steady-state operation i.e data transmission. Then each CH creates a TDMA schedule in each cluster to organize the communication among cluster members. When the non CH nodes receive the TDMA scheme, nodes send their data to the CH once per frame during their allocated transmission TDMA slots. This allows the radio components of each non-cluster-head node to put the sleep mode at all times except during its transmit time, thus minimizing the energy dissipated in the individual sensors. After a certain amount of frames i.e. a TDMA round, the network re-elects CHs and re-form clusters. Then CH, after combining all the received data, will send the results to the BS. Besides, to prevent the interaction of the transmissions which occur in clusters at the same time, LEACH uses different CDMA codes. Existing CH chooses randomly a unique code from a list of spreading codes. The CH filters all received energy using this spreading code. Consequently, the radio signals of the neighbouring nodes are filtered out hence interference of the transmission of the nodes is minimized.

While many homogeneous LEACH variants have been developed as described above, there are also heterogeneous cluster based WSN routing protocols. SEP is a fundamental protocol for WSNs and contains advanced nodes which are fitted with extra energy resources. SEP uses a weighted election probability based approach to determine CHs according to the residual energy of each node. In SEP, \( m \) corresponds to fraction of the advanced nodes which are fitted with \( a \) times more energy than the normal nodes. As a consequence, the total initial energy of the WSN is increased by \( 1 + a.m \) times. The additional energy of the advanced nodes forces them to be elected as CHs. Each node is informed the total energy of the network in order to adjust its election probability to become a CH according to its residual energy. The remaining energy values of normal and advanced nodes are transmitted to the CHs while members send data. The remaining energy values of the nodes are delivered to the BS by using CHs. The results of the simulations of the SEP show that, SEP provides significant energy savings, lifetime gains and throughput improvement when compared with LEACH for both homogeneous and heterogeneous scenarios.

DEEC is another heterogeneous and distributed clustering protocol where the CHs are determined by a probability based on the ratio between residual energy of each node and the average energy of the network. The nodes which have high residual energy are more probable to become CHs. Adaptive approach of DEEC provides for controlling the energy consumption of the nodes to provide the energy-efficiency. In DEEC, there are advanced and normal nodes. \( m \) is the fraction of the advanced nodes and these nodes have \( a \) times more energy than the normal ones. Therefore, DEEC network has \( a.m \) times more energy and virtually am more nodes. The results of the simulations of DEEC protocol indicate that, DEEC prolongs the time of first node death when compared with LEACH variants and SEP in heterogeneous networks.

II. SIMULATION ENVIRONMENT AND PARAMETERS

The simulations are conducted in MATLAB. 100 sensor nodes are randomly deployed in a 100 m x 100 m field as shown in Fig. 1 and BS is placed outside of the sensor field which have coordinates of (150,50). Same simulation parameters of LEACH are used for all simulations in this paper. Each simulation is realized for 100 independent iterations to obtain more scalable results. Table I summarizes the simulation environment parameters used for simulations.

![Fig. 1. The randomly deployed sensor nodes in a WSN.](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network area</td>
<td>100 m x 100 m</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>Base station coordinates</td>
<td>(150,50)</td>
</tr>
<tr>
<td>Initial energy per node</td>
<td>2 J</td>
</tr>
<tr>
<td>Data packet size</td>
<td>6400 bits</td>
</tr>
<tr>
<td>Control Packet Size</td>
<td>200 bits</td>
</tr>
<tr>
<td>Transceiver Energy (( E_{elec} )</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Aggregation Energy per Bit (( E_{agg} ))</td>
<td>5 nJ/bit/signal</td>
</tr>
<tr>
<td>Free Space Amplifier Energy (( E_{fs} ))</td>
<td>10 pJ/bit/m²</td>
</tr>
<tr>
<td>Multipath Amplifier Energy (( E_{mp} ))</td>
<td>0.0013 pJ/bit/m²</td>
</tr>
</tbody>
</table>

III. SIMULATION RESULTS

In this section, the performance comparisons of LEACH, SEP and DEEC protocols are made for residual energy, number of alive nodes and lifetime. To obtain more scalable results, 100
iterations are realized. For each iteration, the average values of the results are collected. In SEP and DEEC simulations, same parameters are used. The nodes in SEP and DEEC networks are equipped with 250 J total initial energy.

A. Residual Energy

Fig. 2 illustrates the total residual energy of the nodes in terms of rounds. With advanced, it can be observed that DEEC and SEP provide significant energy savings when compared to LEACH. After 2000 rounds, while LEACH holds 15% of its initial total energy, SEP and DEEC hold approximately 30% of their initial total energies. When the network lifetime ends under LEACH, SEP and DEEC still maintain approximately 10% of its initial total energy. For same simulation parameters, DEEC and SEP have approximately same performance.

B. Number of Alive Nodes

Fig. 3 shows the number of alive nodes thus the network lifetime for LEACH, SEP and DEEC. Under SEP and DEEC, the network lifetime increases from 3237 rounds to 5000 rounds, approximately 50% improvement compared to LEACH. Although, node deaths start earlier under DEEC, since the CHs are abused, the rate of the number of dead node increases is significantly less and this yields to a longer lifetime. One major difference between LEACH and DEEC can also be observed from this figure. Right after the first node death under LEACH, the remaining node deaths will follow quickly. But with DEEC, node deaths are distributed evenly for the network lifetime. SEP provides to delay first node failure in the network because it uses advanced nodes. It allows to select advanced nodes to become CHs more frequently thus it provides to delay the CHs in the network. SEP also utilises CH determination approach which provides to select CH nodes according to their residual energy.

For each algorithm, the simulations are repeated 100 times for different topologies and the maximum and average observed lifetimes are presented in Table II as well as the initial network energies. DEEC’s conservative energy consumption ratio increases the lifetime of a WSN significantly. DEEC outperforms LEACH and SEP.

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>Average Lifetime</th>
<th>Maximum Lifetime</th>
<th>Initial Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEEC</td>
<td>5221</td>
<td>5941</td>
<td>250 J</td>
</tr>
<tr>
<td>SEP</td>
<td>5059</td>
<td>6177</td>
<td>250 J</td>
</tr>
<tr>
<td>LEACH</td>
<td>3478</td>
<td>4216</td>
<td>200 J</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

Nowadays, saving energy, extending lifetime and designing green networks [5, 6] for WSNs has become an essential research area. By placing or determining advanced nodes and providing more energy-efficient CH determination approaches, DEEC and SEP decrease the energy consumption of cluster formation. The results of the simulations demonstrate that, SEP and DEEC algorithms provide significant energy efficiency, lifetime gains when compared with LEACH. DEEC also delays the first node death and provides equal alive node distribution in the WSN.

References


Robots are located at every stage of our lives with developing technologies. Interest in the field of robotics is increasing every day. There isn’t a course on robotics in primary school curriculum in Turkey. Facilities of educational institutions is limited and primary school teachers is inadequate in robotic. Therefore, many educational institutions aren’t given to students in robotics education. Shown in programming courses in private schools, Lego Mindstorm robot module constitutes awareness in children from early ages. This study aims to increase the interest of children in Turkey to robotics. To improve the students’ creativity and motivation, a simple robot design supported with Augmented Reality education related notes have been prepared. A simple model for the implementation of robotics in primary education has been constituted.

Keywords— Robotic, Education, Augmented Reality, Primary School

I. INTRODUCTION

Today, in the face of rapidly evolving technology and increasing information needs to be trained individuals who can adapt to change. Knowledge of age together with our ability to quickly increase, based on the technology and the training of information technology, including new technologies, the question of how it illustrates the way in the field of educational technology [1].

A new term in the field of technology is Augmented Reality (AR) which is some- how can be considered as a different version of virtual reality. It allows users to get experience of using virtual objects in real world. So, Augmented Reality is rapidly growing and developing. This technology supplements the real world with composite 3D virtual objects that are integrated into the real world. This technology is very interesting and interactive and therefore there is a vast range of potential applications of Augmented Reality such as in the field of medicine, manufacturing, urban planning, architecture, archaeology, education and many more [2].

According to the research, it was determined that 4-5-6 graders have more creative and original ideas, according to the 7th and 8th grade students [3]. In elementary schools of Turkey, computers first come to mind when term of technology is said. However, we see that take out different terms the mention of technology in the World. Robotics comes at the beginning of these terms.

Robotics is an area that needs to be focused on in primary school age children. With applications of robot design, robot contests, robot projects, it is seen that children gain a lot of property, such as problem-solving, finding practical solutions to problems, learning by doing and experiencing and critical thinking [4].

This research aims to provide information on the use of robotics in the education of primary school age children, and to help planning applications about robotics in Turkey. It also aims to provide the students get closer with the robotic and technology. In this context, a document prepared that supported by augmented reality robot construction and programming for the 4th and 5th grade students who are studying in primary schools.

II. RELATED WORK

When the studies related to robotics in schools are analyzed, it is seen that students were affected in a positive way [5].

In the study of Vollstedt, Lego Robotics learning program has been performed on about 300 students in secondary schools [6]. As a result of the analysis made, it is seen that students' interest and knowledge of science, technology, engineering and mathematics has been increased with robotics [2]. Hacker has developed “Robolab” project for his work, and observed the effect of robotics on learning basic science and mathematics principles of 3-6 grade children. With the study, it is seen that the stu- dents were affected positively with learning by doing and living practices [7]. Teixeira uses robotics in secondary
education and suggests usage of robots as a pedagogical agent especially in project development [8].

Balaji et al. created a robotic education tool named “FASTBOT" to create an awareness before the students plan their career. This tool provides students to pro- gram, find solutions to the given tasks and apply their knowledge in addition to pro- gramming [9]. Wei et al. in their study, present a general technical creative design- teaching scheme that includes Augmented Reality. The result of study that Keller method is also used , show that the proposed teaching scheme significantly improves learning motivation, student creativity and teaching of creative design [10][11].

Augmented reality applications related to education seem to increase in the world and Turkey. Comparing with traditional classes, it is seen that augmented reality applications are increasing the students learning rate [12][13]. As a result of spreading usage of smart phones, the number of augmented reality applications and researches on mobile devices are increasing [14].

One of the augmented reality technologies thought that can be used in education is “Google Glass” technology created by Google. The study of Demirer and Erbaş, "Augmented Reality Applications in Educa- tion: Google Glass Case" can be shown as an example. In this study, the information about augmented reality and Google Glass technology is given, studies about the usage of this technology are reviewed and suggestions are made [15].

Küçük et al. developed an augmented reality application for learning English. In the application, the success, comportment and cognitive load levels of secondary school students in English learning were examined [16]. As a result of studies, it was determined that students are satisfied, their level of anxiety is low and they want to use the application in the future in their classes.

Çetinkaya and Akçay in their study "Augmented Reality Applications in Educa- tional Environments", say that augmented reality applications for different needs are started to be used widely in the world and foresee that FATIH project is an important opportunity to spread augmented reality in Turkey [17].

The use of augmented reality is increasing in daily life, too. Large companies are developing applications to their customers and users. The companies BMW, Marshall and Ikea develop some of these applications. The glasses designed by BMW for these of maintenance and repairing is shown in Figure 1 [18].

Marshall company has developed applications for wall color test in the house. Images of the application is shown in Figure 2 [19].

The images of the augmented reality application developed by Ikea to show table, armchair etc. home accessories in 3D is shown in Figure 3 [20].
III. METHOD

Turkey’s private schools use robotics kits, "PicoCricket" and "MINDSTORMS® LEGO® NXT" which has developed by MIT University and Lego Group, on their robotic courses. Students produce original designs by using robotic kits. They learn gears and simple machine mechanisms. They try the mechanisms they produced using sensors and motors. Robotic studies aims to gain skills that students use technology, design, science and mathematical operations about the subject.

Students think them- selves as a scientist, an engineer or a designer when they work on robotic studies. They begin to examine the problems in daily life in time. They feel more confidence about creating solutions to these problems [21].

There are a variety of applications that can run in mobile operating systems to develop Augmented Reality projects. Some of them are Alive, Augmented, Aurasma, Blippar, Junaio, Layar and Wikitude in applications. The features of these programs are presented in Table 1 [14].

<table>
<thead>
<tr>
<th>App</th>
<th>Operating Sys.</th>
<th>Working Media</th>
<th>3D Media</th>
<th>Social Media</th>
<th>Position Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alive</td>
<td>A/I/M</td>
<td>PC/SP/T</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Augment</td>
<td>A/I</td>
<td>SP/T</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Aurasma</td>
<td>A/I</td>
<td>SP/T</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Blippar</td>
<td>A/I/M</td>
<td>SP/G</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Junaio</td>
<td>A/I</td>
<td>SP/G</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Layar</td>
<td>A/I</td>
<td>SP/T</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Wikitude</td>
<td>A/I</td>
<td>SP/T/G</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 1. Augmented Reality Programs

Videos are added to document using Aurasma Studio which is one of the freeware augmented reality program. Aurasma Studio software is an easy to use application. Aurasma Studio, unlike the other applications, allows to create augmented reality projects with personal mobile devices.

Aurasma Studio application needs to be downloaded to smart phone via the web site of the application. In this application, any image prerecorded databases, whether in the form of a banner outside or a computer located image, it could be scanned to be transformed into an interactive view rather than an image.

As one of the application's functionality, while video viewing on tablet or phone device pointed on an image, if the device removed from image video stops and if the device replaced back on the image, video will continue where it left.

For example, on Figure 4, the application executed by a picture, an animation presented to the user's access. Simple images can be a gate to easily access different videos or animations [22].

![Fig. 4. Aurasma Samples](image1)

Application website’s image is shown in Figure 5.

![Fig. 5. Aurasma Studio Screensh](image2)

Document has been prepared for use by LEGO® MINDSTORMS® robotic kits. Students do not need to know programming. Students take information about the robotic kits via the help of the document. Students see what can do with robotic kits using both verbal and video sources.

Document has benefited from the Lego’s instruction manual for the verbal section. The document consists of 3 pages. Each pages has and image supported by Augmented Reality. First visual is made public information about the robotic kit. The second visual was introduced kind of robots that can be made using Lego blocks. There is also information in latest visual that sensors can be used. An example is shown in Figure 6 from the document.
methods to arouse interest in the field of robotics in order to increase motivation of students, using robotics for their creative skills. These studies suggest a different training method combining augmented reality technology with robotics.

These studies can be expanded, starting from elementary school to teenagers at the university level. It could be provided courses about robotics for students which could be accessed whenever they want. Also augmented reality technology could be used in different areas of education.

Fig. 6. Augmented Reality Example

Document example, supported with augmented reality is shown in Figure 7.

Fig. 7. Example of Augmented Reality on Document

IV. RESULT AND DISCUSSIONS

When analyzed international studies on robotics, it is seen that robotics education is given importance. Recently in Turkey is given courses of robotics education. Augmented Reality applications will be more imported to improve robotic educations.

The importance of robotics education in primary schools is also emerging at this point. It is necessary to find different
REFERENCES


[18] BMW Augmented Reality, https://www.youtube.com/watch?v=P9KPIJA5yds


Wavelet Based Medical Image Watermarking Scheme for Patient Information Authenticity

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Abstract—Telemedicine is an important technique that permits transmission of medical and imaging data from one place to other, ensures the reliability of data and provides a convenient communications between patient and medical staff. In this study, Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) based medical image watermarking method that hides the patient information into medical image without affecting the image quality is proposed for the purpose of authentication. At the watermark (secret image containing patient information) embedding process, a chaotic map called as Arnold Cat Map (ACM) is applied to the watermark to improve the security of the method.

So that the aim of the proposed watermarking scheme is personal authentication by ensuring the perceptual invisibility, PSNR (Peak Signal-to-Noise Ratio) values are calculated during the simulations. According to the experimental results, we can say that the proposed method provides higher PSNR values than compared current methods. Furthermore, in simulations DWT and SVD based watermarking scheme is implemented as chaotic and non-chaotic watermarking scheme to investigate the effect of chaotic map on the performance of the proposed algorithm.

Keywords—Medical image watermarking, discrete wavelet transform, singular value decomposition, PSNR.

I. INTRODUCTION

Telemedicine is a technique which aims to provide clinical and health assistance to remote areas by utilizing telecommunication and information technologies. Through telemedicine, patients benefit from far away specialists for medical diagnosis without travelling. By telemedicine, it is possible to transmit medical and imaging data from one place to other and to communicate the patient with the medical staff. Transmitted medical images help physician to decide diagnostic procedures. Then, to evaluate the progress of treatment, telemedicine can be used again [1].

During the transmission, medical image may be destroyed by intruders or attacked by noise. We need to ensure reliable data transmission to not cause the wrong diagnosis. For this purpose, digital image watermarking is found to be an effective and promising mechanism by the researchers [8, 9].

Digital image watermarking is a technique of embedding a secret information (watermark) to a cover image. There are three common requirements for watermarking schemes: robustness, capacity and invisibility. However, there is a trade-off between these requirements. For example, a stronger watermark can be used to increase the robustness, but in this case watermark becomes noticeable. On the contrary, increasing the capacity decreases the robustness. Consequently, one must make a choice between these three requirements according to the application. For telemedicine technique, during the storing and transmission of medical images (i.e. Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and X-ray imaging) the security of the digital data has a critical importance. Furthermore, we need to embed patient’s information to the medical image without causing any perceptual changes. So, the perceptual invisibility of the watermarking scheme must be very high to maintain the quality of original medical image [2, 3].

According to the embedding domain, watermarking techniques can be classified in to two groups as spatial domain watermarking techniques and frequency domain watermarking techniques. In spatial domain techniques, the secret data is directly inserted into the samples of the cover signal. In frequency domain techniques, embedding process is performed in the frequency domain by modifying the coefficients of the transformed image. The transformed image can be obtained by applying Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT) or Redundant Discrete Wavelet Transform (RDWT) [4]. Although spatial domain techniques has low computational cost and are less complex, the transform domain techniques are most popular because of their significant advantages such as robustness and imperceptibility.

In this study, DWT and SVD based medical image watermarking scheme is proposed. In the proposed scheme, patient’s information is embedded to the medical image as a binary watermark. The aim of this study is to embed the patient’s information to the medical image without degrading the quality of medical image for personal authentication. At the watermark embedding stage, original cover (medical) image is decomposed by DWT into LL, LH, HL and HH sub-bands. Then SVD is applied to each sub-band. On the other side, ACM and SVD are performed for
the original watermark, respectively. Then, the singular values of the medical image is added to the singular values of chaotic watermark in all sub-bands. Finally, by using invers SVD and inverse DWT the watermarked image is obtained.

The paper is organized as follows. In section II, in order to better understand the proposed algorithm, DWT, SVD and ACM are discussed. Watermark embedding and extracting algorithms are explained step by step in section III. Section IV gives the experimental results and compares the proposed method with related studies. Finally, Section V concludes the paper.

II. APPLIED TECHNIQUES

In this section, the techniques used in the proposed method are explained briefly to better understand the watermark embedding and extraction steps.

A. Discrete Wavelet Transform (DWT)

DWT is a common tool used in watermarking schemes which transforms the image from spatial domain to frequency domain. It is shown in many papers that DWT is superior then other transform techniques in watermarking algorithms. By applying DWT, 1-D original signal is separated into the low-frequency and high frequency sub-bands. This process is called as decomposition and gives us DWT coefficients. The original signal can be reconstructed by using DFT coefficients. This reconstruction process is referred as inverse DWT (IDWT) [5].

By performing DWT on image (2-D signal) one time, the image is split into four sub-bands, LL₁, LH₁, HL₁, and HH₁.

LL₁ is the low frequency sub-band and it contains the maximum of energy while the other sub-bands are middle (LH₁, HL₁) and high (HH₁) frequency sub-bands. These middle and high frequency sub-bands represent the edges, outline, texture and other detail information of the original signal. If we want to perform again DWT to signal, we should apply the DWT to the LL₁ sub-band. This process can be repeated until we get the appropriate decomposition level for our application.

Watermark embedding process is done by changing the wavelet coefficients according to the embedding algorithm. The watermark can be embedded either in low- frequency sub-band or high- frequency sub-band with respect to the purpose of the application. Embedding watermark to the high- frequency sub-band provides high imperceptibility advantage but robustness and stability of the scheme will be decreased. Robustness can be improved by embedding watermark to the middle a frequency sub-band but this will cause decrement of imperceptibility.

B. Singular Value Decomposition (SVD)

In recent years, SVD has become an extremely valuable tool in signal processing area. Image compression, data hiding, noise reduction and image watermarking are just some applications of SVD [6].

Given the data matrix A of dimension N x N which has the independent column (i.e. rank (A) = N), there are two unitary matrices V and U such that

\[ A = USV^T \] (1)

Where S = diag(σ₁, σ₂, …, σₘ) is an diagonal matrix. Singular values are ordered as σ₁ ≥ σ₂ ≥ … ≥ σₘ > 0. The Equation (1) is mathematical the representation of SVD.

SVD is an optimal decomposition method that concentrates the maximum signal energy into as few coefficients as possible. From the image processing point of view SVD has three main advantages: i) it can applied to any dimension of image matrix, ii) after applying SVD to image the singular values S corresponds to the brightness of image while U and V denotes the geometric properties of the image, iii) the slight variations of singular values of an image may not affect the human visual perception. This stability property of SVD is the main reason why it is preferred for watermarking applications [7].

C. Arnold’s Cat Map (ACM)

Chaotic signals has very broad range of application in secure communications, signal processing and cryptography because of their inherent properties that can be taken into account such as high complexity. There are many chaotic maps in literature appropriate for image processing applications. ACM is one of the most famous chaotic map used for randomizing the pixel locations in the image matrix. This randomizing provides high security for the image watermarking schemes. ACM can be applied for only square matrix. For N x N square image matrix it can be expressed as

\[
\begin{bmatrix}
{x}_{n+1} \\
{y}_{n+1}
\end{bmatrix} = \begin{bmatrix}
\frac{1}{b} & a \\
1 & b + 1
\end{bmatrix} \begin{bmatrix}
{x}_n \\
{y}_n
\end{bmatrix} \text{mod } N = A \begin{bmatrix}
{x}_n \\
{y}_n
\end{bmatrix} \text{mod } N. \quad (2)
\]

where \((x_0, y_0)\) and \((x_{n+1}, y_{n+1})\) are the locations of pixels before and after iterations, respectively. In Equation (2) the coefficients \(a\) and \(b\) are selected such as \(\text{det}(A)=1\) [5].

After applying a few iterations into original image the locations of pixel will be scrambled but when the iterations are repeated enough we will attain the original image again. There is no any formula for exact number of iterations for given dimension of image, but for higher dimension we expect higher iterations. ACM transformation for different iterations is illustrated in Fig. 1. As a conclusion the number of iterations both in watermarking embedding and extracting must be selected carefully [10].
A. Watermark Embedding

In our algorithm, CT, MRI and X-ray images are used as a cover image. During the embedding algorithm, two, three and four level decomposition of DWT are performed to these images, respectively. The steps of the embedding algorithm are given below:

1. By performing the appropriate decomposition level to cover image, the image is divided into LL, LH, HL, and HH sub-bands.

2. SVD is applied to the each sub-band of the cover image as follows:
   \[ A^i = U^i S^i V^i T \]  (3)
   where \( A \) is the sub-band of cover image and \( i \) denotes the LL, LH, HL, and HH sub-bands, respectively.

3. We attain chaotic watermark \( W_{ACM} \) by performing 76 iterations ACM to the watermark image (W).

4. SVD is applied to chaotic watermark \( W_{ACM} \) as follows:
   \[ W_{ACM} = U_{ACM} S_{ACM} V_{ACM}^T \]  (4)

5. Singular values \( S^i \) of cover image are modified with singular values \( S_{ACM} \) of chaotic watermark image
   \[ S'^i = S^i + \alpha S_{ACM} \]  (5)
   where \( \alpha \) is fixed scaling factor for all sub-bands and \( i \) represents LL, LH, HL, and HH sub-bands.

6. Inverse SVD is performed by using modified singular values
   \[ A'^i = U^i S'^i V^i T \]  (6)
   where \( i \) represents LL, LH, HL and HH sub-bands, again.

7. Finally, we implement inverse DWT to get the watermarked image.

B. Watermark Extraction

The steps of the watermark extraction algorithm are given below:

1. We decide the most appropriate level of DWT and applied DWT to the watermarked medical images. By this way, we get LL', LH', HL' and HH' sub-bands.

2. SVD is applied to LL', LH', HL' and HH' sub-bands, as follows
   \[ A'^i = U^i S'^i V^i T \]  (7)
   where \( I \) denotes LL, LH, HL and HH sub-bands respectively.

3. Singular values of watermark image are computed as follows,
   \[ S^W = (S^W - S^i)/\alpha \]  (8)
   where \( \alpha \) is fixed scale factor for all sub-bands.

4. By applying inverse SVD, we obtain the chaotic watermark
   \[ W_{ACM} = U^i S^W V^i T \]  (9)

5. Finally, we perform 20 iterations ACM to \( W_{ACM} \) (for 128x128 image matrix 96-76=20), in order to get the original watermark image.

IV. EXPERIMENTAL RESULTS

The purpose of this section is to investigate the efficiency of the proposed medical image watermarking method by performing simulations. In order to expand the application areas of the proposed scheme the CT, MRI and X-ray medical images are utilized. MATLAB computer program is used during the simulations. The size of CT image is 1024x1024, MRI image 512x512 and X-ray image is 2048x2495. The watermark image of size 128x128, includes the patient’s information such as the name, surname, age and type of medical image. Since the medical images are used for diagnosis and treatment, the quality of medical image is crucial. So the imperceptibility of
watermark must be very high. In order to investigate the imperceptibility of the watermarking schemes, the peak signal-to-noise ratio (PSNR) criterion is commonly used in the literature. PSNR can be defined as the similarity between the original cover(medical) image and watermarked medical image and can be calculated as follows,

$$PSNR = 10 \log_{10} \left( \frac{\max(\{X(i,j)\}^2)}{MSE} \right)$$  \hspace{1cm} (10)

where the mean square error (MSE) is defined as:

$$MSE = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} [X(i,j) - Y(i,j)]^2$$ \hspace{1cm} (11)

In Eq. (11), size of the images are $m \times n$. The higher PSNR values means that the watermark is better hidden. The other criterion for evaluating the performance of algorithm is Normalized Correlation (NC) which measures the similarity between the original watermark and extracted watermark [2, 4]. It is computed from:

$$NC = \frac{\sum_{k=1}^{m} \sum_{j=1}^{n} W(k,j) W'(k,j)}{\sqrt{\sum_{k=1}^{m} \sum_{j=1}^{n} [W(k,j)]^2} \sqrt{\sum_{k=1}^{m} \sum_{j=1}^{n} [W'(k,j)]^2}}$$ \hspace{1cm} (12)

where $W$ and $W'$ represent the original and extracted watermarks, respectively. The correlation coefficient takes on values in the interval [-1, 1]. If it is near 0, the extracted watermark is completely uncorrelated with the original one. Generally, the NC is considered acceptable if it is 0.75 or above.

In Table 1, PSNR and NC values are given for CT, MR and X-ray image. The watermarking algorithm is performed with and without chaos. As can be seen from the table, for both cases the PSNR values are almost over 90 dB and NC values are over 0.98. According to these results it is clear that the imperceptibility of watermark in the proposed scheme ensures the desired demand. In the Table 2, the comparison between the proposed scheme and reference [2] is illustrated. Watermark is embedded in LL sub-band for comparison. The superiority of our method can be seen obviously. Furthermore, in Figure 2 each step of proposed watermarking scheme is shown with corresponding images. The other advantage of proposed scheme is that acquired imperceptibility values are independent from decomposition level of DWT.

V. CONCLUSION

In this study, DWT and SVD based medical image watermarking scheme is proposed. In the proposed scheme, patient’s information is embedded to the medical image as a binary watermark. CT, MR and X-Ray images are used as medical image in the simulations. At the watermark embedding process, a chaotic map called as ACM is applied to the medical image to improve the security of the method.

The aim of the study is to hide patient’s information to the medical image without degrading the quality of medical image for personal authentication. By calculating PSNR and NC values we prove that the proposed method ensures the desired property. Furthermore, we exhibit that the proposed method provides higher PSNR values than compared current methods. The proposed scheme can be applied independently of type and size of medical image.

REFERENCES


<table>
<thead>
<tr>
<th></th>
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<tr>
<td>CT</td>
<td>46.01 dB</td>
</tr>
<tr>
<td>MRI</td>
<td>47.20 dB</td>
</tr>
<tr>
<td>X-Ray</td>
<td>49.58 dB</td>
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</tbody>
</table>

Table 2. Comparison between proposed scheme for (sub-band LL) and reference [2].

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>CT</td>
<td>46.01 dB</td>
</tr>
<tr>
<td>MRI</td>
<td>47.20 dB</td>
</tr>
<tr>
<td>X-Ray</td>
<td>49.58 dB</td>
</tr>
</tbody>
</table>

Table 1. Results for proposed medical image watermarking scheme.
for Medical Image Authentication”, 17th International Conference on Computer and Information Technology (ICCIT), 2014.


Comparison of the effect of unsupervised and supervised discretization methods on classification process

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Abstract— Most of the machine learning and data mining algorithms use discrete data for the classification process. But, most data in practice include continuous features. Therefore, a discretization pre-processing step is applied on these datasets before the classification. Discretization process converts continuous values to discrete values. In the literature, there are many methods used for discretization process. These methods are grouped as supervised and unsupervised methods according to whether a class information is used or not. In this paper, we used two unsupervised methods: Equal Width Interval (EWI), Equal Frequency (EF) and one supervised method: Entropy Based (EB) discretization. In the experiments, a well-known 10 dataset from UCI (Machine Learning Repository) is used in order to compare the effect of the discretization methods on the classification. The results show that, Naive Bayes (NB), C4.5 and ID3 classification algorithms obtain higher accuracy with EB discretization method.

Keywords— Discretization, Supervised and Unsupervised Discretization, Continuous Features, Discrete Feature, classification algorithms.

I. INTRODUCTION

Many Machine Learning and Data Mining classification algorithms have application possibility only to the discrete data. But, most data in practice have continuous feature. The datasets usually contains mixed forms of nominal, discrete, and continuous data. Discrete values have intervals between a continuous series of values. The number of continuous values for an attribute can be endless, but the number of discrete values may be few or have an end value [1]. An example to continuous features is blood sugar content. Whereas an example of discrete features is gender. Process of converting continuous values to discrete values is called discretization. Discretization is generally used to sort and reshape continuous variables of attributes into categorized features. However, there are endless possibilities of discretization methods depending on the intervals which exist within domain. The idea of discretization is to divide the range of a numeric or ordinal attribute into intervals through user given or computed cut points. [2] made a comparison between unsupervised discretization method (Equal width, Equal frequency) and supervised discretization method (Entropy-based, Purity-based) from classification accuracy point of view. They found that the classification accuracy of the classification algorithms (Naive-Bayes, C4.5) significantly improved when features of the datasets were discretise using an entropy-based discrete method. At [3], the results of comparison between using discrete method and continuous method for six datasets showing that the performance of the classification accuracy is improved, when the features of datasets discretise. Studies for Cluster Algorithm also can be used as discretise values. [4] proposed accounting the interdependencies among different attributes and discretise the data using minimum entropy with minimum description length as the stopping criteria, used K-mean clustering methods and shared nearest neighbour. While [5] used the K-means clustering algorithm for discretization.

In this study, we applied supervised EB and unsupervised EW and EF discretization methods on 10 UCI dataset with continuous values. These datasets are applied to classification algorithms that work on discrete features, and then the accuracy of classification methods are compared. At the next section, the discretization methods unsupervised EW & EF and supervised EB are explained. At section 3, the classification algorithms are given. The experimental results are shown at Section 4 and the paper is concluded at Section 5.

II. DISCRETIZATION AND CLASSIFICATION OF DISCRETIZATION METHODS

Data discretization process is a method aims to reduce the volume of distinct values of continuous variables through dividing its range into limited set of unrelated intervals and then relating these intervals by specific descriptive labels. Usually discretization steps are sorting continuous values, finding cut points and finally applying conversion process [1].

Discretization methods are categorized along different needs, discretization of continuous values to obtain higher accuracy rate on handling data with high cardinality. Main classification of discretization is as supervised and unsupervised. Generally the categorization of the supervised and unsupervised discretization techniques depends on class information, for example if the discretization process uses class information, then we say it is supervised discretization. Otherwise, it is called as unsupervised discretization [1], [2]–[3].

A. Unsupervised Discretization Methods

The simple discretization (equal-width and equal-frequency interval binning) is among the unsupervised discretization methods and binning does not use class information.
Continuous ranges are subdivided into smaller ranges through user specified width or frequency. Usually in the unsupervised discretization methods, the number of parts must be supplied by the user [1], [2]–[6].

1) Equal Width Interval Discretization: The simplest discretization method is equal-width interval discretization which divides the range of observed values for a feature into equal sized bins represented by $k$ that is a parameter supplied by the user [1]–[2]. The process involves finding the minimum and maximum observed values through sorting of a continuous feature, $A = \{a_0, a_1, a_2, \ldots, a_{n-1}, a_n\}$, $a_{\text{min}} = a_0$ and $a_{\text{max}} = a_n$. $A$ is a continuous value array. Computing the interval may be done by dividing the range of the observed values for the variable into equally sized bins using the following formula: [1], [2]–[5].

$$\text{Interval} = \frac{a_{\text{max}} - a_{\text{min}}}{k}$$

$$\text{Boundaries} = a_{\text{min}} + (i \times \text{interval})$$

The boundaries can be formed by $i = 1, \ldots, k-1$ using the above formula. Equal Width Interval discretization steps as shown in Fig. 1. And these steps are given as an example in Table I below. Where $I$ is the instance, $T$ is the temperature, $C$ is the classes value, $A$ is the sorted value of $T$ and $D$ is the discretised value of $T$.

**Input:** data is the array having continuous values of the attribute, $A = \{a_0, a_1, a_2, \ldots, a_{n-1}, a_n\}$ and $k$ is the number of parts, where $k > 0$;  
**Output:** data having discrete values.

Step 1: Sort the value $A$ in increasing order  
Step 2: Calculate the interval by equation 1
Step 3: Binning the data by boundaries formula and determine the split point for $A$
Step 4: The value of attribute in the array must be placed in the same boundaries

**Fig. 1 Equal Width Interval Discretization algorithms**

**TABLE I**  
EXAMPLE FOR EQUAL WIDTH DISCRETIZATION

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
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<tr>
<td>T</td>
<td>85</td>
<td>90</td>
<td>86</td>
<td>96</td>
<td>80</td>
<td>70</td>
<td>65</td>
<td>95</td>
<td>75</td>
<td>91</td>
</tr>
<tr>
<td>C</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>A</td>
<td>65</td>
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<td>75</td>
<td>80</td>
<td>85</td>
<td>86</td>
<td>90</td>
<td>91</td>
<td>95</td>
<td>96</td>
</tr>
</tbody>
</table>

Here $a_{\text{min}} = 65$, $a_{\text{max}} = 96$, $n = 10$, and let $k = 3$

So $\text{Interval} = 10/(3-1) = 5$ and around (interval) Then $i = 0$; each bining contained approximately 3 element, the rise is added to the last part.

<table>
<thead>
<tr>
<th>T</th>
<th>1</th>
<th>2</th>
<th>1</th>
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<th>1</th>
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<td>D</td>
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<td>2</td>
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</tbody>
</table>

2) Equal Frequency Interval Discretization: In the equal-frequency discretization algorithm the minimum and maximum values are determined for discretized attribute, and then all values are sorted in ascending order, and sorted continuous values divided into $k$ intervals in a way that each interval contains approximately $n/k$ data instances with adjacent values, $A = \{a_0, a_1, a_2, \ldots, a_{n-1}, a_n\}$ where $n$ is a number of element in $A$.

And $A$ is set of data with array having continuous values [1], [2], [5]–[7]. In proportional $K$-interval discretization method, the data instances with identical value must be placed in the same interval, so it is not always possible to generate exactly $K$ equal frequency intervals [7]. Equal Frequency discretization steps as shown in the Fig. 2. And these steps are given as an example in Table II below. Where $I$ is the instance, $T$ is the temperature, $C$ is the classes value, $A$ sorted value of $T$ and $D$ is a discretised value of $T$.

**Input:** data is an array having continuous values, $A = \{a_0, a_1, a_2, \ldots, a_{n-1}, a_n\}$ and $k$ is the number of parts. Where $k > 0$;  
**Output:** data having discrete values.

Step 1: Sort the value $A$ in increasing order  
Step 2: Determine the split point for $A$ and calculate the data instances in each interval by dividing the number of elements in the array by number of parts.
Step 3: The value of an attribute in the array must be placed in the same boundaries

**Fig. 2 Equal Frequency Discretization algorithms**

**TABLE II**  
EXAMPLE FOR EQUAL FREQUENCY DISCRETIZATION

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>85</td>
<td>90</td>
<td>86</td>
<td>96</td>
<td>80</td>
<td>70</td>
<td>65</td>
<td>95</td>
<td>75</td>
<td>91</td>
</tr>
<tr>
<td>C</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>A</td>
<td>65</td>
<td>70</td>
<td>75</td>
<td>80</td>
<td>85</td>
<td>86</td>
<td>90</td>
<td>91</td>
<td>95</td>
<td>96</td>
</tr>
</tbody>
</table>

Here $a_{\text{min}} = 65$, $a_{\text{max}} = 96$, $n = 10$, and let $k = 3$

So Interval $= 10/(3-1) = 5$ and around (interval) Then $i = 0$; each bining contained approximately 3 element, the rise is added to the last part.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>1</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>0</th>
<th>2</th>
<th>0</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

**B. Supervised Discretization Methods**

This discretization method converts numerical data to their categorical counterparts and use class information while choosing discretization nodes. Entropy based discretization is an example of this method [1], [2]–[5].

1) Entropy Based Discretization: This method uses division approach. Entropy (or information content) is calculated based on class labels. Intuitively works towards purifying each data group by finding the best cut points, so each data in the pure groups will have the same class label as much as possible. It is characterized by finding intervals that gives the maximum information gained [1]–[8]. The formula to calculate Entropy is as follows;

$$E(S, A) = - \sum_{i=1}^{n} P_i \log_2(P_i)$$

$$P_i = \frac{v_i}{v}$$

Entropy means “impurity”. But the impurity here means: diversity, having too much data with different specifications in one group. When calculating entropy, we will first calculate
entropy for estimated class value \(E(S)\). Then we will calculate entropy for specified cut points \(E(S, A)\). Finally, the best cut point by calculating information gained by the following equation is determined [1–8].

Information Gain = \(E(S) – E(S, A)\)

Entropy based discretization pseudo code is shown in Fig. 3 below. All these steps are given as an example in Table 3 below.

Input: Data is an array having continuous values, \(A = \{a_{0}, a_{1}, a_{2}, \ldots, a_{n}, a_{n+1}\}\)

Output: Data has discrete values.

Step 1: sort the value \(A\) in increasing order

Step 2: calculate entropy for class data

Step 3: determine the best split point for \(A\) by

- Calculate Entropy for each split point
- Calculate information gain for each split point

Step 4: select the split point with highest information gain

Step 5: recursively the partition on each split point when terminate once information gain falls below a certain threshold or once you reach a specified number of bins.

A. Decision Tree Algorithm

Decision trees are frequently used data mining approaches for classification and estimation. Despite the fact that other methods such as ANN can be used for classification, decision trees provide advantage of easy interpretation and comprehensibility to the decision makers [3]. Classification of the data using decision tree technique is a two step process comprising learning and classification. A previously known education data is analyzed by the classification algorithm in order to constitute a model during the learning phase. The constituted model is shown as classification rules or a decision tree. During the classification phase, on the other hand, test data is utilized in order to determine the accuracy of the classification rules or a decision tree. If the accuracy is in an acceptable range then the rules are used for classification of new data. It should be determined that which domains will be used in what type of order to constitute the tree. Entropy metric is the most widely used measurement for this purpose. The results obtained using the domain are uncertain and instable proportionally to the entropy measurement in that domain. Thus the minimum entropy or maximum information gain measurement of the domains are used in the roots of the decision tree. Entropy can be mathematically defined as; if \((p_1, p_2, \ldots, p_n) = \sum_{i=1}^{n} p_i \log_2 p_i\) then the sum of all these probabilities should be exactly 1. Finally the information gain is calculated for each \(p\) via the following equation [9–10].

\[ \inf \text{gain}(D, S) = H(D) – \sum_{i=1}^{n} P(D_i)H(D_i) \]

In a decision tree, all paths from the root node to the leaf node proceed by way of AND [11]. There are multiple modules of the decision tree algorithms [10], ID3 and C4.5 modules are used in this paper.

B. Naïve Bayes Algorithm

Naïve Bayes Classifier is an approach of probability, which can be used with a proposition that first seems to be very limiting in classification problems [10]. This proposition is the necessity of independency of each defining quality or parameter to be used in pattern identification in respect of statistics. No matter how this proposition is limiting the application field of Naïve Bayes Classifier, this approach yields results comparable to more complex methods such as ANN by stretching statistical independency condition.

Naïve Bayes Classifier is the simplified state of Bayes theorem by means of the independency proposition. Bayes theorem is expressed with the following equation:

\[ P(A|B) = \frac{P(B|A)P(A)}{P(B)} \]

\( P(A|B)\): The probability of incident A when incident B is realized

\( P(B|A)\): The probability of incident B when incident A is realized

\( P(A)\) and \( P(B)\): Prior probabilities of incidents A and B.

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>EXAMPLE FOR ENTROPY-BASED DISCRETIZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8 9 10</td>
<td></td>
</tr>
<tr>
<td>T 85 90 86 96 80 70 65 95 75 91</td>
<td></td>
</tr>
<tr>
<td>C no no yes yes no no yes yes yes</td>
<td></td>
</tr>
<tr>
<td>A 65 70 75 80 85 86 90 91 95 96</td>
<td></td>
</tr>
</tbody>
</table>

\( \text{No} = 4, \text{Yes} = 6 \text{ probability } \text{No } P_{\text{No}} = 4/10 = 0.4 \text{ probability Yes, } P_{\text{Yes}} = 6/10 = 0.6 \)

Entropy (Play) = \(E(4,6) = E(0.4, 0.6) = -0.4 * \log_2(0.4) – 0.6 * \log_2(0.6) = 0.970\).

Let \( k = 2 \) (80 and 86) then.

For 1. Split \(<80 = \{65, 70, 75, 80\}\) and \(>80 = \{85, 86, 90, 91, 95, 96\}\)

For 2. Split \(<86 = \{65, 70, 75, 80, 85, 86\}\) and \(>86 = \{90, 91, 95, 96\}\)

Calculate entropy and information gain for each split then chose the split with the highest information gain.

Entropy \(E = \Sigma p_i \log_2 (pi)\)

Entropy for split 1 = 0.954 and Entropy for split 2 = 0.888.

Information Gain = \(E(S) – E(S, A)\)

Info for split 1 = 0.970 - 0.954 = 0.016 and

Info for split 2 = 0.970 - 0.888 = 0.082 then

\( D = \{0, 1\} \)

III. CLASSIFICATION ALGORITHMS

Classification concept is basically the distribution of the data among predefined various classes on a dataset [1]. Classification algorithms learn this distribution type from the given education cluster and they try to distribute data when unclassified test data are received. The values indicating these classes on the dataset are named as labels and they are used in order to denote the classes either for education and test. Some classification algorithms process according to categorical values (Decision Tree, Naïve Bayes) while others process with numerical values (ANN) [1].
Here, prior probabilities add subjectivity to the Bayes theorem. In other words, for instance, \( P(A) \) is the information that is obtained prior to any obtained data about incident \( A \). On the other hand \( P(B|A) \) is post probability because it gives information about the realization probability of incident \( B \) when incident \( A \) is realized after data collection \([1]–[10]\).

IV. THE EXPERIMENTAL RESULTS

In this study, using discretization methods of unsupervised (EW and EF) and supervised (EB) to convert an attribute’s continuous value of UCI dataset of Table IV into discrete values. Where \( NS \) is The Number of continuous Attributes, \( ND \) is The Number of discrete Attributes, \( NI \) is The Number of Instance and \( NC \) is The Number of Classes. Using Machine learning classification algorithms (NB, ID3, C4.5), we carried out the classification process on discrete datasets of converted values. Number of parts used in EW and EF discretization methods are \((k = 3 \text{ To } 22; k=2)\), the means \((3, 5, 7, ..., 21)\) are used, and at each \( k \) value classification performance is calculated, as a result, we have taken the average of overall part numbers according to the high performance value of each classification algorithm, in this case \( k = 9 \), in Table V and VI we have given classification accuracy according to the value of \( k \). In EB discretization method, as we mentioned above, the number of parts is calculated according to the data information gain, each attribute of data set is divided into different number of parts. In Table V, VI and VII classification results are given according to discretization methods used.

Properties

### TABLE IV

**NAME AND PROPERTIES OF DATASETS**

<table>
<thead>
<tr>
<th>Datasets name</th>
<th>NS</th>
<th>ND</th>
<th>NI</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast Cancer Wisconsin</td>
<td>9</td>
<td>0</td>
<td>699</td>
<td>2</td>
</tr>
<tr>
<td>Pima Indians Diabetes</td>
<td>8</td>
<td>0</td>
<td>768</td>
<td>2</td>
</tr>
<tr>
<td>Glass Identification</td>
<td>9</td>
<td>0</td>
<td>214</td>
<td>6</td>
</tr>
<tr>
<td>Iris</td>
<td>4</td>
<td>0</td>
<td>150</td>
<td>3</td>
</tr>
<tr>
<td>Stat log Heart</td>
<td>5</td>
<td>8</td>
<td>270</td>
<td>2</td>
</tr>
<tr>
<td>Australian Credit</td>
<td>6</td>
<td>8</td>
<td>690</td>
<td>2</td>
</tr>
<tr>
<td>German Credit</td>
<td>7</td>
<td>13</td>
<td>1000</td>
<td>2</td>
</tr>
<tr>
<td>E.coli</td>
<td>7</td>
<td>1</td>
<td>336</td>
<td>8</td>
</tr>
</tbody>
</table>

### TABLE V

**CLASSIFICATION ACCURACY OF EW**

<table>
<thead>
<tr>
<th>Datasets name</th>
<th>NB</th>
<th>ID3</th>
<th>J4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast Cancer Wisconsin</td>
<td>97.07</td>
<td>95.16</td>
<td>95.31</td>
</tr>
<tr>
<td>Pima Indians Diabetes</td>
<td>74.74</td>
<td>51.82</td>
<td>75.13</td>
</tr>
<tr>
<td>Glass Identification</td>
<td>68.69</td>
<td>76.63</td>
<td>72.43</td>
</tr>
<tr>
<td>Iris</td>
<td>93.33</td>
<td>90.66</td>
<td>94.00</td>
</tr>
<tr>
<td>Stat log Heart</td>
<td>81.44</td>
<td>62.59</td>
<td>79.25</td>
</tr>
<tr>
<td>Australian Credit</td>
<td>85.36</td>
<td>67.97</td>
<td>84.78</td>
</tr>
<tr>
<td>German Credit</td>
<td>76.50</td>
<td>56.50</td>
<td>71.50</td>
</tr>
<tr>
<td>E.coli</td>
<td>83.33</td>
<td>62.20</td>
<td>76.19</td>
</tr>
</tbody>
</table>

### TABLE VI

**CLASSIFICATION ACCURACY OF EF**

<table>
<thead>
<tr>
<th>Datasets name</th>
<th>NB</th>
<th>ID3</th>
<th>J4.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast Cancer Wisconsin</td>
<td>97.42</td>
<td>93.82</td>
<td>95.42</td>
</tr>
<tr>
<td>Pima Indians Diabetes</td>
<td>75.91</td>
<td>51.69</td>
<td>75.13</td>
</tr>
</tbody>
</table>

The analysis of the results given in Tables V, VI and VII, from 8 datasets show that in EW method provides high classification accuracy for only Breast Cancer Wisconsin and Iris datasets and in EF method provides high classification accuracy Glass Identification and German Credit datasets while in EB method provides high classification accuracy for the remaining four datasets. In general supervised EB provides better accuracy then unsupervised EW and EF.

V. CONCLUSIONS

Discretization algorithms are known to have advantages and disadvantages relative to one another. Several new methods have been developed keeping these advantages and disadvantages in mind. As it is mentioned before; such as, in equal width discretization method, even if this bare discretization method is attractive among the others, there are reported opinions about major loss of data after discretization process, because of determining the gap width is not done correctly during the division into equal intervals. Other methods, such as the EW and EF require the user to enter the parameters while EB method determines the parameters itself. It is possible to say that, in this case, if user entered values are wrong parameters it could pose a problem in terms of results obtained. Data discretization process plays an important role in the data classification process, since it is the process of entropy based discretization data depends on the class of data in discretization data the discretization is relatively true, and it increases Probability of data classification is relatively. As a result of this study in categorization algorithms (NB, ID3, J4.5) which discretization method gives better performance than the others.

REFERENCES


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Abstract— Multivariate mapping is the visual exploration of multiple attributes using a map or data reduction technique. The simultaneous display of sometimes multiple features and their respective multivariate attributes allows for estimation of the degree or spatial pattern of cross-correlation between attributes. Multivariate mapping integrates computational, visual, and cartographic methods to develop a visual approach for exploring and understanding spatiotemporal and multivariate patterns. More than one attribute can be visually explored and symbolized using numerous statistical classification systems or data reduction techniques. In this sense, clustering analysis methods can be used for multivariate mapping. k-means and k-medoids methods which are non-hierarchical clustering analysis methods were analyzed in this study. The aim of this study is to determine the success of the spatial analysis of the multivariate maps produced by these methods. For this aim, classes and multivariate maps created with these methods from traffic accident data of two different years in Turkey were presented. In addition usability of such maps in risk management and planning was discussed.

Keywords— multivariate mapping; data mining; cluster analysis; visualization; cartography

I. INTRODUCTION

Multivariate mapping is the graphic display of more than one variable or attribute of geographic phenomena. The simultaneous display of sometimes multiple features and their respective multivariate attributes allows for estimation of the degree or spatial pattern of cross-correlation between attributes. Multivariate mapping integrates computational, visual, and cartographic methods to develop a visual approach for exploring and understanding spatiotemporal and multivariate patterns [1].

A fundamental issue in multivariate mapping is whether individual maps should be shown for each attribute or whether all attributes should be displayed on the same map ([2], p.327). Producing separate maps for each attribute would make it difficult to compare two objects which have various attributes. Therefore methods in which various attributes are shown in the same map are preferred more. In this sense, Trivariate Choropleth Map which is created by overlapping of two colored choropleth map [3]-[6], Multivariate Dot Maps method in which specific color or symbol is used for each attribute in the map [7], Multivariate Point Symbol methods which are used when multivariate data can be shown with point symbols [8]-[15], method in which combining different type of symbols is used for representing multivariate data [16] and method of separating different attributes from integral symbols [17] can be listed.

Different from the methods above, in order to represent many attributes in the same map, classification method based on clustering methods in data mining can be used as well. With the use of clustering methods, similar aspects of different spatial objects can be revealed by considering more than one attribute [18]-[19]. In this sense, spatial analyses that would make important contributions for risk analysis, planning etc. can be done.

It is quite important to make use of more than one attributes of current spatial event and determine similarity of spatial events in order to detect future events. For this aim, different spatial and non-spatial analysis methods are used for determining common properties of the spatial events. In this context, [20], [21], [22] and [23] used different clustering methods for determining common properties of different spatial events. Mapping of spatial events according with common properties is also significant for estimating types and effects of future events. Multivariate maps of occurred spatial events are more effective on determining common properties of spatial events and planning investments according to these properties. The aim of this study is to determine the success of the spatial analysis of the multivariate maps produced by k-means and k-medoids clustering analysis methods. For this aim, k-means and k-medoids methods are used for designing multivariate mapping of traffic accidents in Turkey with data of two different years, and result maps are compared. Success of these methods is determined with comparison of maps designed in different years according to two different methods.

In this study, Cluster Analysis and k-means and k-medoids methods in the second section, application in the third section will be explained in details, results and suggestions will be shared in last section.

II. CLUSTER ANALYSIS

Cluster analysis is the process of grouping information in a data set according to specific proximity criteria. Similarity of element in the same cluster should be high, similarity between clusters should be low [24]. In the process of classification, classes are determined before. In clustering method, classes
are not determined before. Data are separated different classes according to the similarity of data obtained.

Cluster methods are classified in different ways in various resources. In general sense, cluster methods can be classified as hierarchical and non-hierarchical methods [2].

- Non-hierarchical Methods: In non-hierarchical methods, n objects are divided into k clusters according k number (k<n) given before. This method divides data in a way that there will be at least one object in each cluster and each object will be included at least in one cluster [25].
- Hierarchical Methods: Hierarchical clustering methods group data objects in tree structure. Hierarchical clustering methods are classified as agglomerative or divisive according to hierarchical division being bottom-up or top-down [26].

In this study, k-means and k-medoids methods from non-hierarchical methods will be analyzed.

A. K-Means Method

This algorithm which was introduced by Mac Queen for the first time in 1967 is a cyclical algorithm in which clusters are continuously renewed until the most suitable solution is attained. General logic of k-means algorithm is to divide a data set composed of n data object to k clusters determined depending on preliminary information and experience of researcher. The aim is to provide the intracluster similarity is high, but the intercluster similarity is low. Similarity of clusters is calculated with the mean value of objects.

The k-means procedure is summarized as below [25]:

Input:
- k: the number of clusters,
- D: a data set containing n objects.

Output: A set of k clusters.

Method:
1. (1) arbitrarily choose k objects from D as the initial cluster centers;
2. (2) reassign each object to the cluster to which the object is the most similar, based on the distance between the object and the cluster mean;
3. (3) update the cluster means, i.e., calculate the mean value of the objects for each cluster;
4. (4) repeat until no change; (Fig.1)

Fig. 1 Clustering with k-mean Algorithm [26]

B. K-Medoids Method

In this algorithm which was developed by Kauffman and Rousseeuw in 1990, instead of mean value of each cluster, an object in each cluster is taken as representative. This representative object, called a medoid, is meant to be the most centrally located object within the cluster [25]. After k medoids chosen for k-clusters are determined, each remaining object is clustered with the representative object to which it is the most similar [27].

Steps of k-medoids algorithm are summarized as below [28]:
1. (1) Determination of k-cluster number.
2. (2) Choose of k objects as initial medoids
3. (3) Assign the remaining objects to cluster which has the most similar x medoid.
4. (4) Calculate aim function (sum of distances of all objects to the closest medoid)
5. (5) Arbitrarily choose of y point which is not medoid.
6. (6) If change of x and y would minimize aim function, change the place of these two points (x and y)
7. (7) The process is repeated between 3rd and 6th step until there is no change.

III. APPLICATION

Casualties, injuries and financial damages as a result of traffic accidents are among the most important problems of Turkey. When data of the last 5 years are analyzed, it is seen that there have been more than 1,000,000 traffic accidents, 145,000 of them ended up with death and injury, and nearly 1,060,000 of them results with financial damage. 4000 people lose their life on average in these accidents and nearly 250,000 people are injured. It is quite important to make use of more than one current traffic accidents attributes and determine similarity of traffic data on city basis in order to detect measures to be taken for traffic security in Turkey and future investments to be done. For this aim, in this study, clustering analysis will be made in 3 different methods by using number of motor land vehicles based on city, number of traffic accidents resulting in death and injury, number of casualties and injuries (4 different values) for the years 2011 and 2012 prepared by Turkish Statistical Institute (TÜİK) and multivariate maps will be produced according to analysis results. Maps designed for both years with 3 different methods were compared, it will be evaluated which method is suitable for the success of multivariate mapping and clustering.

In the application of clustering analysis methods, RapidMiner software developed in Dortmund Technology University Artificial Mind Unit by Ralf Klinkenberg, Ingo Mierswa and Simon Fischer was used. Multivariate maps were designed by ArcGIS software developed by ESRI group.

A. Multivariate Map Design with k-means Method

RapidMiner software was used in application of k-means method. As a result of test made in this sense, k cluster number is 5, number of highest iteration that would be made during operation of algorithm for once is 100, and maximum cycle of algorithm is 35. The method was applied separately for 2011 and 2012 data. Centroid Tables of clusters generated as a result of clustering processes are given in Table 1 and Table 2.
With the help of classes obtained by using 4 different values (number of motor land vehicle, number of traffic accidents resulting in death and injury, number of casualties and injuries) in clustering processes, multivariate maps showing similarity of traffic accidents on city basis for Turkey were designed (Fig. 2).

TABLE I
CENTROID VALUES OF CLUSTERS GENERATED WITH K-MEANS METHOD FOR 2011 DATA

<table>
<thead>
<tr>
<th>Number of Motor Land Vehicle</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2147538.3</td>
<td>763392.7</td>
<td>452479.6</td>
<td>224008.6</td>
<td>62987.3</td>
<td></td>
</tr>
</tbody>
</table>

| Number of Traffic Accidents with Death - Injury | 12102.3 | 6210.7 | 3753 | 2037.4 | 623.1 |
| Number of Death | 195 | 147.7 | 104.8 | 68.8 | 24.2 |
| Number of Injuries | 19310.5 | 9957.7 | 6330.2 | 3665.2 | 1377.1 |

TABLE II
CENTROID VALUES OF CLUSTERS GENERATED WITH K-MEANS METHOD FOR 2012 DATA

<table>
<thead>
<tr>
<th>Number of Motor Land Vehicle</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2250907</td>
<td>800977.3</td>
<td>370089</td>
<td>141262.4</td>
<td>51899.9</td>
<td></td>
</tr>
</tbody>
</table>

| Number of Traffic Accidents with Death - Injury | 13427 | 7607.7 | 3544.2 | 1500.9 | 581.9 |
| Number of Death | 226 | 160.3 | 75.5 | 44 | 20.6 |
| Number of Injuries | 21119 | 11899 | 6015.5 | 2857.2 | 1155.7 |

B. Multivariate Map Design with K-medoids Method

RapidMiner software was also used in application of k-medoids method. Different from k-means algorithm, k-medoids process operator was used instead of k-means operator. In this scope, k cluster number was again taken as 5, and maximum cycle of algorithm was taken as 35. Centroid Tables of clusters generated as a result of clustering processes are given in Table 3 and Table 3.

Again with the help of classes obtained by using 4 different values in clustering processes with k-medoids method, multivariate maps were designed for the years 2011 and 2012 (Fig. 3).
### TABLE III
**CENTROID VALUES OF CLUSTERS GENERATED WITH K-MEDOIDS METHOD FOR 2011 DATA**

<table>
<thead>
<tr>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Motor Land Vehicle</td>
<td>1771711.7</td>
<td>443392.2</td>
<td>280032</td>
<td>91045.2</td>
</tr>
<tr>
<td>Number of Traffic Accidents with Death – Injury</td>
<td>10858.3</td>
<td>3743.8</td>
<td>2111.1</td>
<td>1998.8</td>
</tr>
<tr>
<td>Number of Death</td>
<td>175.7</td>
<td>112.9</td>
<td>66.7</td>
<td>33.7</td>
</tr>
<tr>
<td>Number of Injuries</td>
<td>16757.7</td>
<td>4660.4</td>
<td>3901.4</td>
<td>1816.2</td>
</tr>
</tbody>
</table>

### TABLE IV
**CENTROID VALUES OF CLUSTERS GENERATED WITH K-MEDOIDS METHOD FOR 2012 DATA**

<table>
<thead>
<tr>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Motor Land Vehicle</td>
<td>1854920.8</td>
<td>426523.3</td>
<td>164097.7</td>
<td>78071.2</td>
</tr>
<tr>
<td>Number of Traffic Accidents with Death – Injury</td>
<td>12070.7</td>
<td>4424.9</td>
<td>1730.2</td>
<td>831.3</td>
</tr>
<tr>
<td>Number of Death</td>
<td>203.3</td>
<td>87.4</td>
<td>49.3</td>
<td>31.1</td>
</tr>
<tr>
<td>Number of Injuries</td>
<td>18676.7</td>
<td>6642.9</td>
<td>3288.4</td>
<td>1657.2</td>
</tr>
</tbody>
</table>

**FIG. 3** Multivariate maps designed with K-medoids for the years 2011 (above) and 2012 (below)

### IV. CONCLUSIONS

In the scope of multivariate mapping, more than one attribute can be displayed in separate maps or in the same map. Designing separate maps for each attribute would make it difficult to compare two objects which have various attributes. Therefore methods in which various attributes are shown in the same map are preferred more. One of the methods in which various attributes are displayed in the same map is to generate thematic map classes by determining the effect of different attributes with clustering analysis. In this sense, in this study, considering traffic accidents in 2011 and 2012 in Turkey, number of vehicles in traffic in these years, number of traffic accidents resulting in death and injuries, number of casualties and injuries parameters, multivariate maps were designed with 2 different cluster analysis method.

K-means and k-medoids non-hierarchical clustering algorithms divide n objects into k clusters according to k input parameter. They form the same cluster if objects resemble each other but not with the objects in other clusters. The greatest problem in applying these algorithms is determination of k cluster number. This can be determined with some of the practices experiences. When k=5 cluster number is given for data sets used in the study, it is observed that better clustering
results were obtained. Although clustering success of both algorithms are similar, when centroid tables of clusters formed with both methods (Table 1-4) are observed, it was detected that clusters are separated better in k-medoids algorithm. Since the aim is to provide high intracluster similarity and low similarity between different clusters, it can be said that k-medoids method gives better results for these data. When the maps designed using k-medoids method are examined, it is observed that 61 of 81 cities are located in the same cluster for two years. On the other hand, using k-means method 58 of 81 cities are in the same cluster. These results exhibit that foresights using these methods with 2011 data are highly consistent with 2012 data.

With this study it was shown that by using clustering methods, similar aspects of different spatial objects can be presented by considering more than one attributes. It is thought that by using multivariate maps designed with clustering methods, spatial analyses which have important contributions for practices such as risk management, planning etc. can be made.

REFERENCES

Automatic Voice and Speech Recognition System for the German Language with Deep Learning Methods

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Abstract—In our age, technological developments are accompanied by certain problems associated with them. Security takes the first place amongst such kind of problems. In particular, such biometric systems as authentication constitute the significant fraction of the security matters. This is because sound recordings having connection with the various crimes are required to be analyzed for forensic purposes. Authentication systems necessitate transmission, design and classification of biometric data in a secure manner. In this study, analysis of German language employed in the economy, industry and trade in a wide spread manner, has been performed. In the same vein, the aim was to actualize automatic voice and speech recognition system using Mel Frequency Cepstral Coefficients (MFCC), MelFrequency Discrete Wavelet Coefficients (MFDWC) and Linear. Prediction Cepstral Coefficient (LPCC) taking German sound forms and properties into consideration. Approximately 2658 German voice samples of words and clauses with differing lengths have been collected from 50 males and 50 females. Features of these voice samples have been obtained using wavelet transform. Feature vectors of the voice samples obtained have been trained with such methods as Boltzmann Machines and Deep Belief Networks. In the test phase, owner of a given voice sample has been identified taking the trained voice samples into consideration. Results and performances of the algorithms employed in the study for classification have been also demonstrated in a comparative manner.

Keywords—Boltzmann Machines, Deep Belief Networks.

I. INTRODUCTION

In our day, security problems have been unearthed along with the developments in the technology. Certain studies have been accomplished especially in order to prevent information belonging to some people from being transferred to other people in commercial transactions. Some of such studies are hand script recognition, signature recognition, face recognition, iris recognition and voice recognition [9].

German language belongs to the Germanic branch of Indo-European language family. Approximately 120 million people are speaking German language in the world. In addition, Germany has an important standing in respect of economy, trade, industry and many other fields in the international sense.

For this reason German language is used in a quite widespread manner. However, common usage of this language to such an extent, brings security problems for biometric data in this field. Accordingly this calls for the requirement of a secure, fast automatic voice and speaker recognition.

German language comprises of roots (words) and suffixes & prefixes and included in the inflected languages if we consider properties of the German language. German is written using the Latin alphabet and there are 29 letters in its alphabet. An article appears before each noun in German. Words are pronounced as they are written. In addition, it is distinguished from other languages with various developed sound shifts and intonation.

Various studies have been carried out in order for voice and speaker recognition. Jie-Fu et al. have collected voice samples in Chinese from 7 males and 5 females whose ages were ranging between 25 and 45 [8]. Attempts have been made to identify the owner of the voice by trying to analyze these voice samples by means of their tones, vowels, consonants and syllables. Voice samples have been separated into four frequency groups, and each frequency band has been analyzed. However, this study has not been tested for very big data. In addition, intended success was not exactly achieved since it was performed taking its similarities with the English language into consideration.

Tokuda et al. have developed English speech synthesis system using Hidden Markov Model [4]. This system has been developed for speaker recognition and specifies the structure by changing the voice feature. However characteristic feature of the synthesized voice in the study, is pretty low.

Reynolds et al. have implemented SuperSID project in order to enhance performance of speaker recognition systems [1]. Purpose of this project is to develop speaker recognition systems and employ the most suitable features in order to increase its accuracy. However this study failed to completely achieve the acoustic characteristics of the voice and removal of the noise.

Reynolds et al. have attempted to substantiate speaker identification and verification using Gaussian Mixture Model
Mel shows the frequency of voice tone. Mel smoothen the transition of speech samples between the frames. Hamming window has been used in this signal is divided into frames after the pre-processing step. MFDWC feature extraction method. Speech processing. It is used to extract significant information and features by dividing the sound data to its subsets. Feature extraction ste from men and women. These voice samples were used to create a unique database comprising German voice samples collected from men and women. These sound samples are trained by getting dispersed to various feature vectors with MFDWC, MFCC and LPCC. In the second stage, the feature vectors of the recorded sound signals are trained with classification algorithms, such as Boltzmann Machines and Deep Belief Networks. The gender of the speaker is decided by looking at sound signals at the test data and training data after the system is trained. Furthermore, the classification success in recognizing the gender of speaker has been calculated separately for 1, 3 and 5 and 9 feature vectors and the success of the methods have been presented comparatively by training the feature vectors, obtained from speaking signals with Boltzmann Machines and Deep Belief Networks.

II. FEATURE EXTRACTION METHODS

German language is widely used in economy, industry and trade. Therefore, examinations have been made on German language in this study. The study has been realized on a unique data base, which have been formed from the German sound samples, taken from men and women. These sound samples are trained by getting dispersed to various feature vectors with MFDWC, MFCC and LPCC. In the second stage, the feature vectors of the recorded sound signals are trained with classification algorithms, such as Boltzmann Machines and Deep Belief Networks. The gender of the speaker is decided by looking at sound signals at the test data and training data after the system is trained. Furthermore, the classification success in recognizing the gender of speaker has been calculated separately for 1, 3 and 5 and 9 feature vectors and the success of the methods have been presented comparatively by training the feature vectors, obtained from speaking signals with Boltzmann Machines and Deep Belief Networks.

A. Mel-frequency Discrete Wavelet Coefficients (MFDWC)

The study in question has been performed, based on a unique database comprising German voice samples collected from men and women. These voice samples were separated into various feature vectors with MFDWC, and trained. MFDWC is a feature extraction method employed in the speech processing. It is used to extract significant information and features by dividing the sound data into subsets. Feature extraction steps of MFDWC technique is shown in the Figure 1 [7].

Sample speech signal is shown between the 40-40000 Hz range in the MFDWC feature extraction method. Speech signal is divided into frames after the pre-processing step. Hamming window has been used in this study in order to smoothen the transition of speech samples between the frames. One Mel shows the frequency of voice tone. Mel-scale is scaled between actual frequency of voice signal and estimated voice frequency. For this reason total energy of every frame is calculated. Classification success in speaker identification has been calculated on an individual basis for MFDWC-3, MFDWC-5 and MFDWC-9 vectors by training the feature vectors obtained from voice signals by means of Boltzmann Machines and Deep Belief Networks.

B. Mel Frequency Cepstral Coefficients (MFCC)

MFCC is a feature extraction method, that is used in sound processing. It is used to extract important information and features by dividing the sound data to its subsets. The steps of feature extraction technique of MFCC is indicated in Figure 2 [11].

![Feature extraction steps of MFDWC](image1)

![Feature extraction steps of MFCC](image2)
Two filters are used in MFCC feature extraction method. The first filter has a linear distribution of frequency values under 1000 Hz and the other has a logarithmic distribution of frequency over 1000 Hz. Pre-emphasis stage is the first stage in obtaining MFFC feature vector.

The sound signals, which have high frequency, are passed through a filter at this stage. This way, the energy of the sound is increased at high frequency. The sound signals are analog. The sound signals are converted from analog to digital by getting divided into small frames between 20 and 40 ms during the framing stage and it is divided into N frames. The sound signal is moved by sliding the sound signal at the windowing stage. This way, the closest frequency lines and the frame, which will come by windowing, that is used are combined. The window type, width and sliding amount are determined at this stage. Each of N frames is transmitted from the time space to the frequency space with Fast Fourier Transform (FFT). The spectral features of sound signals are shown in frequency space. MEL spectrum is obtained by calculating the total weight of these spectral features. This MEL spectrum is formed from triangle waves and are formed by getting passed through a series of filters. The logarithm of signal is taken at the stage of MEL spectrum and the signal is transmitted back again from frequency space to the time space. MEL frequency cepstrum factors are obtained by using DCT (Discrete Cosine Transform) in time space.

C. Linear Prediction Cepstral Coefficient (LPCC)

LPCC is a well known and commonly used technique to obtain the characteristic features from sound signals. In this technique, each sample of sound signal is based on the conversion of linear prediction coefficients obtained as a linear weighted total of previous sound signals into cepstral coefficients. This is not a method preferred for sound signals exposed to various environmental effects or noise. LPCC utilizes functions that model the sound path.

LPCC method is obtained by converting LPC coefficients into cepstral coefficients through Fourier conversion. Preliminary process is completed by transmitting speech signal through high filter. Auto correlation characterizes the signal by determining the similarity of each sound signal with itself. This step is materialized in frame of each signal. Signal is analyzed by converting the auto correlation values into LPC parameters by using Levinson-Durbin recursion. In final phase, LPCC parameters are obtained with cepstral analysis [12]. Steps of LPCC feature extraction are provided in Figure 3.

\[
s(n) = \sum_{n=1}^{p} a_i s(n - i)
\]

Fig. 3 Feature extraction steps of LPCC

III. CLASSIFICATION METHODS

Depth learning algorithms are used in certain fields primarily in sound processing in recent years. In particular, depth learning algorithms are developed for the solution of complicated problems. They are comprised of multi layers. Therefore, they may contain numerous hidden information. In this study, two depth learning algorithms are used as Boltzmann machines and Depth belief Networks. Steps of the study are presented in Figure 4.

Receiving of sound records

Extraction of sound features with MFDWC, MFCC and LPCC

Modelling the system by training with depth learning algorithms

Comparison of test sample given with the sound samples in the models

Automatically determining the speaker according to model created

Fig. 4 Study Steps
A. Boltzmann Machines

Boltzmann Machines (BM) are used in the modelling of units between entry layers and hidden layers. Therefore, parameters learnt in hidden layer are the entry parameters for next BM. So, BM is very significant for deep neural networks.

Boltzmann machines are a stochastic process comprised of recursive artificial neural network. It has multilayer structure. It is used frequently for the solution of searching and learning problems. All artificial neural networks are not linked with each other.

Restricted Boltzmann Machines (RBM) are the structures limiting the connections to be formed on the layers between units within the entry layer and the units within the hidden layer. All artificial neural networks are not linked with each other. Sample of RBM neural networks are indicated in Figure 5.

\[
p(l = k|h; \theta) = \frac{\exp(\sum_{i=1}^{n} \lambda_{ik} + a_k)}{Z(h)}
\]  

(2)

Entry signal in Equality 2 is processed through all layers and converted into output multiple distribution. Entry signal is divided into \( k \) and \( e \) in final layer weights between \( k \) class and hidden units are indicated.

It is recommended to materialize the learning of DBM network in two phases. In preliminary training phase as first stage, weight parameters modelling the entry data are learnt. Second phase is referred as finetuning and aims for the learning of network parameters classifying the training set [15].

![Fig. 5 Boltzmann Machines](image)

RBM is a directional graphical model comprising the hidden and visible units on a layer. All hidden units are indicated as dual graph since they are linked with visible units. Creation of RBM model is indicated in Equality 2 [16].

\[
p(v, h, \theta) = \frac{\exp(-E(v, h; \theta))}{Z}
\]

(2)

In this equality, \( v \) indicate the visible unit, \( h \) hidden units, \( \Theta \) model parameters and E function of model comprised of \( (v, h; \theta) Z = \sum_v \sum_h \exp(-E(v, h; \theta)) \) normalization factor.

B. Deep Belief Networks

Depth Belief Networks (DBM) are the architectures providing modelling of data within hierarchical structure. DBM comprised of subsequent connection of multiple RBM materializes the learning process by subsequently training the RBMs creating its structure. Structure of DBM is indicated in the Figure 6. It is formed of numerous hidden layers. Next possibility of each hidden layer for the data of which entry data is given. Weight of subsequent RBMs are found from hidden activities [14]. This possibility distribution is calculated as in Equality 2 [16].

![Fig. 6 Deep Belief Networks Structure](image)

IV. EXPERIMENTAL STUDY AND RESULTS

In this study, an authentic and unique German database has been used. The names, surnames, ages, sexes and speeches of persons have been added into this data base. The different number of feature vectors of sound components have been extracted with MFDWC, MFCC and LPCC feature extraction method. In the next stages, the sound samples have been trained by using methods Boltzmann Machines and Deep Belief Networks. The features of the recorded sound samples have been indicated in Table 1.
Feature vectors of voice components with different quantities; have been extracted by means of MFDWC, MFCC and LPCC feature extraction method. Voice samples have been tested by training them, using available feature vectors by means of Boltzmann Machines and Deep Belief Networks methods.

Success rates of speech samples obtained utilizing MFDWC different feature vectors are given for Boltzmann Machines and Deep Belief Networks in the Table 2. Success in the speaker identification increases as the number of words used increases in all techniques employed. Deep Belief Network gave more successful results when compared to Boltzmann Machines.

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Number of speaker</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>18-25 range speakers</td>
<td>15</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>26-40 range speakers</td>
<td>23</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>41 and more speakers</td>
<td>12</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

Success rates of speech samples obtained utilizing MFCC different feature vectors are given for Boltzmann Machines and Deep Belief Networks in the Table 3. Success in the speaker identification increases as the number of words used increases in all techniques employed. Deep Belief Network gave more successful results when compared to Boltzmann Machines.

<table>
<thead>
<tr>
<th>Feature vectors/Methods used</th>
<th>3</th>
<th>5</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Boltzmann Machines</td>
<td>87.62</td>
<td>82.15</td>
<td>74.62</td>
</tr>
<tr>
<td>Deep Belief Networks</td>
<td>85.03</td>
<td>83.72</td>
<td>56.75</td>
</tr>
</tbody>
</table>

Success rates of speech samples obtained utilizing LPCC different feature vectors are given for Boltzmann Machines and Deep Belief Networks in the Table 4. Success in the speaker identification increases as the number of words used increases in all techniques employed. Deep Belief Network gave more successful results when compared to Boltzmann Machines.

<table>
<thead>
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<th>3</th>
<th>5</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Boltzmann Machines</td>
<td>93.27</td>
<td>94.84</td>
<td>95.61</td>
</tr>
<tr>
<td>Deep Belief Networks</td>
<td>96.71</td>
<td>93.62</td>
<td>97.65</td>
</tr>
</tbody>
</table>

V. CONCLUSION

Voice recognition plays an important role in our day due to security and many other reasons. Person and speaker identification systems have been developed, being based on an unique database obtained by utilizing German language in this study. Classification success of the methods employed in the study have been calculated separately for men and women, and results are demonstrated in a comparative manner. Deep Belief Networks provided more successful results compared to the Boltzmann Machines when the results are taken into consideration. Speaker recognition system is more successful for men compared to the women. 9 feature extraction is more successful compared to the results obtained utilizing for all other feature extraction techniques.

### TABLE I
ATTRIBUTES OF USED DATABASES

<table>
<thead>
<tr>
<th>Age Range</th>
<th>Number of speaker</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td></td>
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</tr>
<tr>
<td>41 and more speakers</td>
<td>12</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE II
SUCCESS IN CLASSIFICATION FOR MFDWC

<table>
<thead>
<tr>
<th>Feature vectors/Methods used</th>
<th>3</th>
<th>5</th>
<th>9</th>
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</tr>
<tr>
<td>Deep Belief Networks</td>
<td>85.03</td>
<td>83.72</td>
<td>56.75</td>
</tr>
</tbody>
</table>

### TABLE III
SUCCESS IN CLASSIFICATION FOR MFCC

<table>
<thead>
<tr>
<th>Feature vectors/Methods used</th>
<th>3</th>
<th>5</th>
<th>9</th>
</tr>
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<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Boltzmann Machines</td>
<td>90.87</td>
<td>91.72</td>
<td>94.67</td>
</tr>
<tr>
<td>Deep Belief Networks</td>
<td>94.67</td>
<td>90.86</td>
<td>95.65</td>
</tr>
</tbody>
</table>
REFERENCES


A Soft-configured Management System for Microcontroller Training Kits

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Abstract—There are many microcontroller training kits available on the market. Most of them are equipped with DIP-switched circuit boards that are configured mostly by students during the experiments. Intensive use of DIP-switch sockets, cables, and materials on the experimental kits leads to circuit breaks and faulty connections easily. Therefore, many institutions face undesired hurdles in maintenance and repairing procedures even though they have skilled technicians or instructors.

In this paper, we have designed and implemented a software-configured microcontroller training set to overcome adverse conditions originated by conventional microcontroller kits such as time-consuming maintenance procedures and circuit faults caused by improper configurations. In doing so, an analog switch matrix board has been designed to perform connections between the microcontroller port pins and external peripherals. The system eliminates the possibility of the user errors or electrical faults caused by improper wiring along with mechanical damages caused by forceful interventions. Hence, the students can concentrate on the technical aspects of the experiment rather than mechanical inconveniences.

The software designed, which manages an analog matrix switch board, has many scenarios and configuration files for each experiment. The students decide the type of the experiment and he/she configures both the microcontroller and the CPLD using software interfaces provided. The CPLD configuration file is fixed for each scenario but the microcontroller hex file must be developed by the students. The CPLD and the 8051 development board are connected to the computer via a USB 2.0 port.

Keywords—Microcontroller, Training Set, Experiments, CPLD, Matrix Switches

I. INTRODUCTION

Since the time microprocessors and microcontrollers courses first appeared at the universities and colleges, there has been always a strong demand for experimental sets to comprehend the backgrounds of the subject. Emerging technologies like flash programming, high-level language compilers, and simulation tools increase the number of candidates who are willing to develop embedded systems. At the same time, many companies promote their chips and education or training kits to draw the attention of the engineers from the world. Initially, the price of the kits was too high for educational institutions. So, many local companies were emerged to market the educational kits for institutions that have short budgets. Since then, several types of experimental kits have been marketed by different producers with diverse elements and components.

Almost all experimental kits have sockets and cable pairs for the connection of the desired experiment. Since each experiment has different connection setup, the users must configure both the cables and sockets on the board before the test run. This procedure should be done with great care and in a proper manner. Despite diligent operations, the user can harm the sockets and cables during the insertion or remove procedures because of the mechanical forces. In addition, the user can connect the ports in the wrong way inadvertently. The potential problems mentioned can increase the time and maintenance cost dramatically along with reduced level of availability of the kits.

In the literature, there are many approaches to ease the laboratory burdens. For example, an educational kit has been designed to configure the program of the microcontroller and port connections in a straightforward fashion. The educational kit also incorporates a software interface to ease the procedure of the experiments [1].

Another paper presents a microcontroller training set which is also supported by training sets and video courses along with a virtual laboratory [2].

In a master thesis, which is the origin of this study, an 8051 based microcontroller training kit and its peripheral modules are connected each other with a matrix switch configured by a CPLD. In that study, there is no software interface used to configure both CPLD and microcontroller devices respectively. However, the user must configure both the microcontroller and CPLD boards manually using software tools provided by manufacturers [3].

An 8-bit Motorola 68HC11 microcontroller training kit employed with RS-232 serial communication has been designed. The connections for each experiment are performed by on-board DIP-switches and the hex code files are downloaded into the chip through RS-232 protocol [4].

Virtual platforms used in embedded systems training are examined and it is claimed that students prefer virtual environments rather than hardware based platforms since they are considered more efficient compared to conventional approaches [5].
An MC68C11/12 based experiment kit has been designed for engineering laboratories. The system includes only hardware based components and modules [6].

An MC68000 microprocessor based standalone educational board has been designed. The board incorporates keypad, LEDs, LCD, DIP switches, 7-segment display, DC motor and a couple of I/O peripherals. All hardware connections are implemented by DIP-switches and cables [7].

A microcontroller (ATmega128) processor based educational kit, which is targeted for bachelor engineering students, has been examined. Again, entire hardware connections are implemented by DIP-switches and cables [8].

In another study, a PIC 16F84 based training program and an accompanying experimental set have been designed. Programme includes some experiments related to basic operations for target microcontroller [9].

In this paper, we propose a new design and test environment used in microcontroller training to eliminate the drawbacks originated from conventional microcontroller experimental kits. The method includes a matrix switch circuit and a user interface to configure the experimental kit within a couple of seconds without mechanical or physical interventions.

II. SYSTEM ARCHITECTURE

The system architecture is consist of 4 main modules as seen in Fig.1:

- The PC and accompanying software
- An 8051-based microcontroller kit
- A Matrix switchboard
- Various experimental modules

![Fig. 1 General system block diagram](image)

Low impedance analog switches, which are types of SP3T (Single pole, three throw-TSSA3359), connect 8-bit microcontroller ports to various peripheral experimental modules such as display modules, keypads and etc. We have used 32 (4x8) analog switches in the whole system. The switches have 1x3 multiplexer behaviour. Thus, any port of the target microcontroller can be redistributed to one of three testing ports. In order to redistribute each bit of the port of the microcontroller, 8 analog switches are required and they are controlled by 2-bit selection signals (IN1, IN2) provided by CPLD outputs as shown in Fig. 2. In fact, the microcontroller has four port sockets deployed with 10-pin IDC headers, however, in each port header two extra pins are used for power pins i.e. GND and VDD. So, there is no need to redistribute those power pins and they are shared with all ports by default.

The software interface developed incorporates following features:

- All configuration procedures have visual icons
- Experiment selection by the user
- HEX file selection and experiment setup facilities
- The circuit schematic of the experiment is loaded on the screen when an experiment is selected.
- ‘Status’ pane shows the procedures step by step to inform the user
- ‘Experiment summary’ pane informs the user on the details of the experiment such as port routing schemes and the materials used

![Fig. 2 Analog matrix switch block diagram](image)

The user can either select regular experiments or user-defined experiments by clicking tabbed windows on demand as
demonstrated in Fig. 3. In the user-defined mode, many types of peripherals such as LCDs, LEDs, and Dip-switches can be selected and all wiring procedures are done by the user directives.

![Image of User Interface](image_url)

Fig. 3. The User Interface

III. HEX FILE AND CONFIGURATION FILE SELECTION

If the user selects a user defined experiment, the hex code of the experiment and C or assembly source code of the experiment must be provided by the user. Having compiled and produced the hex code by any development tool, the ‘open’ button must be clicked to select intended hex file. After hex file selection, “Prepare Experiment” button is clicked and this step causes two consecutive procedures performed: the background worker programs namely Flip.exe and impact.exe are executed respectively. While Flip.exe configures the target microcontroller using the hex file provided, impact.exe configures the CPLD using a jeld file generated for the intended experiment architecture.

When a regular experiment is intended, any desired experiment listed in the pane is selected by clicking the corresponding radio button. The rest of the configuration procedures are performed automatically without the intervention of the user.

IV. CONCLUSIONS

In this paper, we have designed and implemented a user-friendly, low cost and low maintainability laboratory kit used in embedded systems classes. The system includes hardware and software modules and enables students to focus on programming of the embedded system and its modules other than the hardware connection burdens. Since there is no student intervention on the experiment kits, the risk of the mechanical failures or breaks. The system also provides time advantages, thereby promising more experimental opportunities for the students. The system has been tested with a limited number of modules and it would be better if the number of modules is increased.

REFERENCES

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Comparison of Image Rotation And Filtering Operations In Terms of Image Quality Factors

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Abstract— In this study, research was carried out in order to compare the effects of basic imaging applications such as image rotation and image filtering on a noisy image and determine whether image rotating application can be used instead of image filtering application. In the study, it was aimed to compare bilinear, bicubic and nearest methods, among commonly used interpolation methods of image rotating, with average, wiener and median filters, which are the linear filters among image filtering methods, in terms of image quality factors. PSNR (Peak to Signal Noise Ratio), MSE (Mean Square Error), SSIM (Structural Similarity Index) were determined as quality factors to be used in the study, and the processed image was a baboon image, an 8-bit gray-scale image of 512*512 dimension that is the most common image used in image processing.

Keywords— Image rotating, Image filtering, PSNR, MSE, SSIM

I. INTRODUCTION

The noise which is one of the most common encountered problems in image processing operations consists of noises such as photon shot noise, dark current noise, read noise, quantization noise [1]. These noises can occur within the digital systems due to the reasons such as data transmission and data storage. The random noises such as Gaussian Noise and Salt&Paper Noise which are the most commonly used images to model these noises and create algorithms based on this can be created in software environment [1].

The filtering technique which is one of the most frequently used methods to eliminate noises on the image is divided into two: linear, non-linear and spatial-frequency domain filters [2,3]. Linear filters are generally defined as low-pass filters, create blurring on the image and smooth the image while nonlinear filters make the noise filtering process by preserving the edge information defined as a high frequency [3]. Average filter and wiener filter from linear filters and median filter from non-linear filters were used in this study [4, 5, 6]. Image rotating operation is one of the most frequently used applications in program-based and real-time processing in image processing applications [7].

Calculating a new pixel value of each pixel which is known as interpolation during image rotating application is an important operation. For this application, bilinear, bicubic, nearest interpolation methods were developed in the Matlab environment and put into practice [8].

The comparison of image rotating operation and the mentioned interpolation methods noise elimination based on image rotating process idea and implementation with the mentioned filtering methods was a fundamental aim of this study [8].

The measurability and comparability of an application performed are important in terms of science. Therefore, image quality factors are important in image processing applications in order to obtain the measurements of the original image and the image obtained after the performed operation [9].

II. METHOD

A. Image And Noise Filtering

The basic logic of the median filter algorithm that is one of the filters used in this study is realized by a mask and making ascending and descending order of the pixel values within the neighborhood of this mask and appointing the mean value to the center pixel value of the mask determined [4].

The second filter used in this study is called average filter and is one of the most basic linear and spatial filters. The average filter is found by taking the arithmetic average of the sum of pixel values in the whole neighborhood of a mask with certain neighborhood [5].

Another filter used in this study was determined as the wiener filter, and the use of the mentioned filter structure was realized in the Matlab environment and is currently used in academic studies [6].

B. Image Rotating

The methods used in image rotating operation were realized by using the available Matlab functions. The relevant methods are bilinear, bicubic, nearest interpolation methods. The comparison of image rotating operation with image filtering
operation through interpolation methods was studied in the literature, and various image rotating algorithms were observed to have given good results [10,8].

C. Image Quality Factors

Image quality factors are calculated with the relational mathematical functions of the operations performed on images by taking the original image as reference[9]. These were determined as PSNR (Peak to Signal Noise Ratio), MSE (Mean Square Error) and SSIM (Structural Similarity Index). The mathematical expressions of PSNR, MSE, and SSIM, among the relevant quality factors, are as follows [9].

Taking $M \times N$ as the image, 8-bit-gray-scale can be calculated in the $f$ reference image with the same values and in the $g$ test-processed image[9] as follows:

$$
PSNR(f, g) = 10 \log_{10} \left( \frac{255^2}{MSE(f, g)} \right)
$$

$$
MSE(f, g) = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} (f_{ij} - g_{ij})^2
$$

Similarly, mathematical expressions related to SSIM are as follows:

$$
SSIM(f, g) = l(f, g) c(f, g) s(f, g)
$$

"l" represents lighting, "c" represents contrast, and "s" represents correlation. The SSIM factor represents a value within the range of $(0 \rightarrow 1)$. The closer the image value is to the reference image, the closer SSIM value is to 1 [9]. Again, the higher PSNR value is, the closer image to the reference image is obtained, and it takes values between $(0 \rightarrow 99)$ [9].

The farther the MSE quality factor is to the reference image, the higher value MSE takes [9].

The values in this study and their results are shown in the figures and charts in the following section.

III. EXPERIMENT AND RESULTS

The results obtained in this study were obtained as follows in the form of charts and graphs.

Fig.1 512*512 Gray-scale 8-bit baboon image.

Baboon image which is frequently used in image processing studies is shown in Fig.1. Again, zero-padding processing was performed for image rotating operation performed by acquiring new dimensions on the same image, and a sample image rotating of 20 degrees is shown in Fig.2 and Fig.3.

Fig.2 The baboon image to which zero-padding processing was applied

Fig.3 The baboon image to which zero-padding and Salt&Pepper noise adding processing were applied and which was rotated with 20-degree angle of rotation

The PSNR, MSE, SSIM values of the angular changes on the image to which no noise was added in this study are shown in Figure-4, 5 and 6.

Fig.4 Unnoised Baboon Image and 45 degree rotation with PSNR
Again, the change in the noise density which was added to the image in this study and the PSNR values of the relevant image following the application of the median filter were obtained. The results are shown in Fig. 7.

However, the PSNR, MSE, SSIM values in the image to which noise was added and which was rotated at the angles determined in the image and the comparison of the PSNR, MSE, SSIM values in the image of the same picture after filtering through the Average-Wiener filter are shown in Figure-8, 9, 10, 11,12,13.
In this study, as a result of the comparison made between the interpolation methods realized in the image rotating operation during obtaining the values shown in Figure 8-13 and the characteristics of the mentioned filters, it was observed that the characteristics of the filters did not give the expected good results in terms of image quality factors. However, while the conclusion that increasing the values determined as spatial filter masks gave similar results to image rotating operation or it could be used instead of image rotating was valid for the average filter, it was observed to have given an exactly opposite characteristic for the wiener filter. Furthermore, it was observed in the study that the bilinear method which is one of the interpolation methods gave better results that the other methods.

REFERENCES

Implementation of Mainly Used Edge Detection Algorithms on FPGA

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Abstract— Edge detection has important applications area in image processing field. Today, it is a fact that the image processing used in many fields. Therefore, the applicability of edge detection process in the field is also has great importance. In this study, mainly used edge detection algorithms in the literature; i.e., Sobel, Prewitt and Canny algorithms is provided using the verification and inspection on FPGA (Field Programmable Gate Arrays). Program files required for FPGA is prepared by Xilinx System Generator DSP blocks, which can work integrated with Matlab/Simulink. For this study; gray format images, which is stored on the computer has been sent to FPGA with USB configuration port interface on FPGA. Edge detection process is realized by moving subject images from the computer with the same connection to FPGA and then, Sobel, Prewitt and Canny algorithms are applied to the images on FPGA respectively. Edge detection process for the same images are performed by Simulink and FPGA board at the same time and then, edge detected images obtained from these two environment are compared and also it has been observed on the FPGA resource usage.

Keywords— FPGA (Field Programmable Gate Arrays), Sobel, Prewitt, Canny, Matlab/Simulink and Xilinx System Generator, DSP (Digital Signal Processing)

I. INTRODUCTION

Today, with the development of image processing technology it is also used quite a lot. Most of our lives intertwined with a technological structure is wrapped in an image processing device is configured on. The algorithms used in this field of technology with the speed proportional manner are developing very rapidly. Work is done in many areas, i.e.; Security systems, traffic warning systems, microscopy and medical imaging systems, making use of image processing techniques such as remote sensing systems.

One of the most important areas in the image processing is an edge detection process. Edge detection is one of the most important task of finding the image. Edges is the most important information in the image. Human visual system is based on the direct detection of edges [1]. To distinguish objects in the images, the display of details which can not be noticed with the naked eye, in situations such as edge detection algorithms to compare the two different patterns are used quite extensively. Haralick, found that the gradient value using the derivative value interpolation equation is found through applied on pixels in the direction of the gradient on the second derivative method caller has provided a transition to zero [2]. Canny, the implementation of the operator derived from the Gaussian mask derivative based proposed a method [3]. Roberts is the first method used in image processing, Prewitt and Sobel operators are an example to the most appropriate operators [4]. Because image processing and edge detection processing speed for applications that require processing typically computer-based applications, DSP-based methods and FPGA's are used.

We can sort out some work done using image processing FPGA said. Chris and his friends for the detection of tumors in the brain images taken by MRI device, brands have benefited from Xilinx FPGA development board. Implemented on FPGA determined the tumor site with different filters. Create a system in which they work in a way that is integrated with Matlab, compared to other systems available in the literature, 50% less use of resources has been realized [5]. Rodriguez and colleagues while running real-time median filter design on FPGA, have created a system that enables visual identification of errors in production centers [6]. Nelson, a team using different FPGA hardware produced by the master's thesis on Xilinx Spartan-3 FPGA's need to work * .bit extension file has been created with the Xilinx System Generator. Chris and his friends while improving the resolution of an image taken using DSP with FPGA hardware have gained a clearer picture. In this process; They used the Xilinx Spartan-3 FPGA hardware configuration of the image and they have developed the resolution with DSP [8].

This article made a thorough research on the FPGA programmable logic devices and technologies and the basic operators used in edge detection Sobel, Prewitt and Canny operator of the implementation on FPGA and is provided to be examined. In this study, Matlab / Simulink and Xilinx System Generator can run Xilinx integrated DSP blocks in Simulink and Simulink blocks with the tool is used. Due to prepared system 256*256 gray formatted images on computer sent to Simulink and FPGA at the same time and Sobel, Prewitt and Canny operators were applied to the images. In prepared system, data transmission between computer and FPGA is provided with USB configuration port. FPGA's need to work * .bit extension program file has been created with the Xilinx System Generator. In practice, Spartan3E XC3S1600 belonging to the company Xilinx FPGA device is used.
The following sections of this article consists of more than four sections. Scope of issues examined in this section are as follows: Section 2 in this article; edge detection, edge detection methods and general information about the basic edge detection operators are given. At Section 3; information about Xilinx System Generator, which used for programming of FPGA board and Simulink DSP blocks are given. Section 4 in this article; implementation of Sobel, Prewitt and Canny edge detection operator on FPGA and Simulink side is explained in detail. Results and conclusion parts are shown in sections 5 and 6 respectively.

II. EDGE DETECTION AND OPERATORS

Visual system in humans is first trend detection edges in the image of the object located on any image. This is because the stationary location typically does not contain information. In an image, the image improvement is of great importance how important is the determination of the edges. Generally such high levels of image processing in the edge detection operators are implemented as a precursor [9]. Different features depending on optical and shape of an image leads to the formation of the edges. Shape-based features in the appearance of the edges; changes in the direction of surface texture or color, object, borders, colors observed two objects sourced from the top are differences in the appearance and texture [10]. Edges which some of their optical properties are; the direct reflection light, shadows caused from a part of the same object or other objects, reflections arising from the intermediate part of the same object or other objects, texture or color variation [11].

One of the most efficient methods to detect edges in the image that exists is to identify instant gray value changes on the image. One of the main approaches used by many edge detection method which involves calculating the derivative locally. In the first derivative of the edges of the image locally reached the highest value, while the second derivative image in the edge of regional zero. 1st and 2nd derivatives are calculated for the image as a result of this, a local maximum and edges with the zero crossing points for the examination of the image is determined. Fig. 1 shows derivative values of image function at edge points.

![Image](image_url)

Fig. 1 Derivative of edge transition of edge points

A. The First Derivative(Gradient) Based Methods

Gradient based single variable is expressed as the first derivative of a function. This operation is a function which depends on two variables calculated by applying the process according to the 1st derivative of each variable. As an image is expressed as a function of two changes, the necessary information about the direction of the gradient edge angle as can be seen by looking at the size gradient to be applied to the edges in an image display function will give us. \( f(x,y) \) as an equation for an image display function, gradient magnitude and gradient angle is calculated by equations below.

\[
G[f(x, y)] = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} = \lim_{\Delta x \to 0} \frac{f(x+\Delta x,y)-f(x,y)}{\Delta x} \quad \lim_{\Delta y \to 0} \frac{f(x,y+\Delta y)-f(x,y)}{\Delta y}
\]

(1)

\[
G = \sqrt{\left(G_x^2 + G_y^2\right)} \quad \theta = \tan^{-1} \frac{G_y}{G_x}
\]

(2)

Roberts, Sobel, Prewitt and Canny 1st derivative (gradient) based methods are the most well-known among operators.

1) Roberts Operator: Roberts’s operator on the image of a mask with a drizzle of 2x2 at every point allows for the calculation of the approximate gradient vector. The magnitude of the gradient vectors is calculated, it is placed on the edges of a pixel matrix of image size designated image can be obtained.

Gradient operation on the image convolution operation result is calculated using two different masks image horizontally and vertically. The result of using the first derivative of the convolution equation gives two masks, which is given below.

\[
G_x = \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}, \quad G_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}
\]

(3)

2) Sobel Operator: Another fundamental edge detection operator is Sobel. This provides operators with the direction to make an efficient assessment as more independent gradient calculation based on more extensive use operators like Robert [12]. The basic idea underlying the creation of Sobel operator edge can be explained as follows. The total value of the gradient of a digital image to 3x3 neighbourhood center and 4 formed in the direction vector is based on a function that is considered. Sobel horizontal and vertical masks are given below.

\[
G_x = \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}, \quad G_y = \begin{bmatrix} 1 \\ 2 \\ 1 \\ 0 \\ 0 \\ 0 \\ -1 \\ -2 \\ -1 \end{bmatrix}
\]

(4)

3) Prewitt Operator: Prewitt edge operator is an operator that calculates the gradient vector at each point on the image pixels. Found the gradient vector magnitude edge image that made improvements, while the direction of the gradient vector gives the edge direction [13]. Prewitt edge gradient values using the two different masks in horizontal and vertical pixel on the image is calculated by convolution operation. The masks are used during this process include using difference equations.
of the first derivative. Prewitt horizontal and vertical masks are given below.

\[ G_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}, \quad G_y = \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \] (5)

4) Canny Algorithm: Canny has been working for optimum edge detection algorithm [3]. Determining this algorithm has been designed to provide the following features:

- Developing a great possibility that when determining the value of the algorithm places where the edges, the edges are not able to determine locations with a small probability value.
- To be defined edges should be on the edge to be the closest to real edge.
- Real edge should be detected only once.

Canny edge detection algorithm work consists of five steps. These steps are as follows, respectively:

- Smoothing
- Gradient Calculation
- Non-maximum Suppression
- Double Thresholding
- Edge Tracking with Hysteresis

All of the amount of noise present in the images obtained by the camera is inevitable. During the edge detection process on the noise image to image will cause errors need to be cleaned out. In order to cleaning Gaussian filter is applied to the image. This process is for smoothing and equations given below is for Gaussian filter.

\[ G_x = \frac{1}{2\pi\sigma^2} \exp \left( -\frac{x^2+y^2}{2\sigma^2} \right) \] (6)

\[ G = \frac{1}{15} \begin{bmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{bmatrix} \] (7)

For calculation of gradient magnitude and gradient angle Sobel filter are applied to the images and equation (2) is used.

The main objective of making the process non-maximum suppression is sharpen the edge of the image with a blurred gradient magnitude. This process is mainly performed by making all pixel values of the non-local maximum points in the gradient image to zero.

After non-maximum suppression process some of pixel values is not real edge pixels due to noise and color variation. The aim of double thresholding is elimination of these pixels. Canny edge detection algorithm uses two threshold, including high and low thresholds. Edge pixel density greater than high threshold pixels that "strong" as classifying edge pixels which are printed below the lower threshold pixel density. Edge pixel value between the low and high threshold in case the edges of the pixels are "weak" as classified.

After double thresholding process the pixels, which are classified “strong” as determined edge pixels precisely. If the pixels, which outside of that and classified “weak” is neighbourhood of “strong” pixels remain otherwise value of them became zero.

B. The Second Derivative(Laplacian) Based Methods

In this method when we take the first derivative of image function, at the edge points value of derivative become maximum and minimum. After this we take second derivative and it will give us edge pixels at zero values of image function. Noise sensitivity of this method is higher than the first derivative method. Marr-Hildreth(LoG) operator is well known operator for the second derivative based methods [1].

1) Marr-Hildreth(LoG) Operator: Marr and Hildreth applying Laplace filter to image the function passed through the filter Gaussian filters were developed in 1980, allows the presence of edges on the image. High frequency noise on the image cleaning with a Gaussian filter operation, and applying Laplace filter by taken second derivative of image function gives edge detection of image. Equations given below is about Laplacian and Gaussian of image function respectively.

\[ h(x, y) = \nabla^2[g(x, y) * f(x, y)] = [\nabla^2 g(x, y)] * f(x, y) \] (8)

\[ \nabla^2 g(x, y) = \left( \frac{x^2+y^2-2\sigma^2}{\sigma^4} \right) e^{-\frac{(x^2+y^2)}{2\sigma^2}} \] (9)

III. PROGRAMMING FPGA WITH XSG

Xilinx System Generator (XSG) is produced by the Xilinx DSP design tool. This software tool MATLAB model-based design environment that enables the use of Simulink for FPGA. System Generator using the design is carried out using hosts Xilinx special design blocks in DSP functions in Simulink. FPGA program file that is necessary for creating synthesis and placement/ routing steps are automatically executed in this environment.

System Generator is working according to the Simulink model-based design methods. Usually, executable functions are created using standard Simulink blocks. This feature of System Generator is designed using floating point number system without function hardware details. System Generator uses the Xilinx DSP blocks in Simulink and automatically run to perform the core functions of a high degree of conformity of the connection required for the DSP blocks.

The Xilinx DSP block are accessed through the library operated with Matlab Simulink tool. Blocks can be made easily for the search process is divided into sub-categories. "Index" is keeping all blocks and sub-categories shortcuts to frequently used blocks, offers ease of use possibilities. DSP building blocks over 90 in the System Generator to design a DSP system is located. System Generator DSP blocks are located in Matlab/Simulink and its image windows is given in Fig. 2.
System Generator works with standard Simulink models. “Gateway In” and “Gateway Out” is defined as two blocks in Simulink simulation model and they define the input and output of the FPGA device is used. "Gateway In" block, converting floating point to fixed-point number type. "Gateway Out" is transforming the FPGA block out the double-precision number type. After FPGAs limits determined by the gateway blocks, DSP designs using the Xilinx DSP block can be realized. Standard Simulink blocks is not used between the “Gateway In” and “Gateway Out” blocks.

IV. PROPOSED DESIGN AND IMPLEMENTATION

The implementation of edge detection algorithms on FPGA realized in three steps, which are image pre-processing, image post-processing and edge detection with XSG. Addition to this, hardware implementation is realized by using XSG for preparation of programming file (*.bit) for FPGA. Fig. 3 shows system diagram for implementation of edge detection algorithms on FPGA.

A. Image Pre-Processing

During this process the data entry format of the “Gateway In” the blog entry block for FPGA card in gray format image on a computer and converted into serial digital data format. Simulink blocks used in image pre-processing steps are given in Fig. 4.

D. Edge Detection with XSG

In order to implementation of edge detection on FPGA, XSG DSP blocks on Simulink is used. For implementation of Sobel operator, gradient calculation and thresholding operation is done XSG DSP blocks, which is shown in Fig. 7 and Fig. 8 respectively. Gradient calculation blocks give the convolution of Sobel mask coefficient with original image pixels and thresholding blocks give the binary edge detected image with respect to a threshold value.
Implementation of Prewitt operator is done same as Sobel operator. Because only the convolution coefficient of Prewitt mask is different from Sobel operator.

Finally, double thresholding is applied to image pixels and binary edge detected image is obtained. Double thresholding XSG blocks are shown in Fig. 11.

For implementation of Canny algorithm; first of all, Gauss filter is used to remove noise from original image. Fig. 9 shows Gauss filter blocks for XSG.

After that, Sobel operator is applied to image pixels for gradient magnitude and gradient angle calculation. And then, NMS (non-maximum suppression) is applied to image pixels, which is shown in Fig. 10.

V. RESULTS

The proposed work is implemented by using Matlab and XSG (Xilinx System Generator) simulink blocksets. This method has been tested on some standard test image like 'Cameraman'. Fig. 12 shows edge detected images, which are detected by Matlab/Simulink and FPGA board for Sobel, Prewitt and Canny algorithms.
FPGA resource usage of Sobel-Prewitt and Canny algorithms on Spartan3E XC3S1600E is given in Table I and Table II respectively. Sobel and Prewitt resource usage is given in one table, because they use the same resource usage on FPGA.

### TABLE I

**FPGA RESOURCE USAGE FOR SOBEL OR PREWITT**

<table>
<thead>
<tr>
<th>Resources</th>
<th>Used</th>
<th>Available</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Slice Flip Flops</td>
<td>1,404</td>
<td>29,504</td>
<td>4%</td>
</tr>
<tr>
<td>Number of 4 input LUTs</td>
<td>2,201</td>
<td>29,504</td>
<td>7%</td>
</tr>
<tr>
<td>Number of occupied Slices</td>
<td>1,401</td>
<td>14,752</td>
<td>9%</td>
</tr>
<tr>
<td>Total Number of 4 input LUTs</td>
<td>2,369</td>
<td>29,504</td>
<td>8%</td>
</tr>
<tr>
<td>Number of bonded IOBs</td>
<td>17</td>
<td>250</td>
<td>6%</td>
</tr>
<tr>
<td>Number of BUFGMUXs</td>
<td>1</td>
<td>24</td>
<td>4%</td>
</tr>
<tr>
<td>Number of MULT18X18SIOs</td>
<td>18</td>
<td>36</td>
<td>50%</td>
</tr>
</tbody>
</table>

### TABLE II

**FPGA RESOURCE USAGE FOR CANNY**

<table>
<thead>
<tr>
<th>Resources</th>
<th>Used</th>
<th>Available</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Slice Flip Flops</td>
<td>916</td>
<td>29,504</td>
<td>3%</td>
</tr>
<tr>
<td>Number of 4 input LUTs</td>
<td>603</td>
<td>29,504</td>
<td>2%</td>
</tr>
<tr>
<td>Number of occupied Slices</td>
<td>654</td>
<td>14,752</td>
<td>4%</td>
</tr>
<tr>
<td>Total Number of 4 input LUTs</td>
<td>688</td>
<td>29,504</td>
<td>2%</td>
</tr>
<tr>
<td>Number of bonded IOBs</td>
<td>17</td>
<td>250</td>
<td>6%</td>
</tr>
<tr>
<td>Number of RAMB16s</td>
<td>13</td>
<td>20</td>
<td>65%</td>
</tr>
<tr>
<td>Number of BUFGMUXs</td>
<td>1</td>
<td>24</td>
<td>4%</td>
</tr>
<tr>
<td>Number of MULT18X18SIOs</td>
<td>5</td>
<td>36</td>
<td>14%</td>
</tr>
</tbody>
</table>

The proposed designs use low resources on FPGA. Sobel and Prewitt resource usage is same value, because only their convolution mask coefficient is different from each other. Resource usage of Canny algorithm is greater than Sobel or Prewitt, because Canny algorithm includes more processing steps from Sobel or Prewitt.

The performance of edge detected image is analysed by using Mean Squared Error (MSE) and Peak Signal to Noise Ratio (PSNR). Equation (10) and (11) show calculation of MSE and PSNR respectively.

\[
    MSE = \frac{\sum_{m \in M, n \in N} (I_1(m,n) - I_2(m,n))^2}{MN}
\]

\[
    PSNR = 10 \log_{10} \left( \frac{R^2}{MSE} \right)
\]

For MSE value; \(I_1\) is pixel value of original image, \(I_2\) is pixel value of edge detected image, \(M\) and \(N\) is horizontal and vertical pixel size of original image. \(R\) is taken 255 in this work, because original image data format is 8-bit unsigned integer. Table III shows quantitative results of MSE and PSNR values for proposed works.

### TABLE III

**QUANTITATIVE RESULTS OF MSE AND PSNR**

<table>
<thead>
<tr>
<th>Algorithms / Platform</th>
<th>MSE</th>
<th>PSNR (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sobel Simulink</td>
<td>29327.8</td>
<td>3.458</td>
</tr>
<tr>
<td>Sobel FPGA</td>
<td>30149.5</td>
<td>3.338</td>
</tr>
<tr>
<td>Prewitt Simulink</td>
<td>31137.2</td>
<td>3.198</td>
</tr>
<tr>
<td>Prewitt FPGA</td>
<td>31345.8</td>
<td>3.169</td>
</tr>
<tr>
<td>Canny Simulink</td>
<td>31447.1</td>
<td>3.155</td>
</tr>
<tr>
<td>Canny FPGA</td>
<td>31497.8</td>
<td>3.148</td>
</tr>
</tbody>
</table>

MSE gives mean square difference between original image pixel and edge detected image pixel. If this difference is high, this means that similarity between images is low [14]. For edge detection process, high MSE means that edge detection performance is better. Therefore low PSNR value gives better edge detection performance [15].

### VI. CONCLUSION

In this proposed work, edge detection algorithms used in literature is introduced. Implementation of Sobel, Prewitt and Canny edge detection algorithms are done in Matlab/Simulink and FPGA board at the same time. When we look at the resource usage on FPGA board, proposed designs used small part of FPGA resources. If we analysis edge detection performance due to Matlab/Simulink and FPGA platform, we can see that MSE values of edge detected images from FPGA is greater than Simulink and therefore PSNR values of edge detected images from FPGA is less than Simulink platform. Because of this, results have shown edge detection performance of FPGA is better than Matlab/Simulink. Another performance investigation is that algorithms, which used for edge detection. That is Prewitt operator gives better results than Sobel operator due to edge detection performance because of its MSE and PSNR values. Canny algorithm has the best edge detection performance than Sobel and Prewitt operators. Because, it has highest MSE and lowest PSNR values comparing with them. As a result, more complex system can be implemented on FPGA, and advantages of edge detection implemented on
FPGA is that; it is field programmable and economic for
design, it has flexible structure and parallel processing
capability.

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Investigating the Effects of Facial Regions to Age Estimation

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Abstract— Aging process causes evident alterations on human facial appearance. Real world age progression on human face is personalized and related with many factors such as, genetics, living style, eating habits, facial expressions, climate etc. The wide degree of variations on facial appearance of different individuals affects the age estimation performance. In accordance with these facts discovering the aging information contained in facial regions is an important issue in automatic age estimation. Thus the facial regions emphasizing the aging information can be used for more accurate age estimation. In this context, age estimation performances of facial regions (eye, nose, mouth and chin, cheeks and sides of mouth) are investigated in this paper. For this purpose, an age estimation method is designed to produce an estimate of the age of a subject by using the texture features extracted from facial regions. In this method the facial images are warped into the mean shape thus variations of head pose and scale are eliminated and the texture information of facial images are aligned. Then the holistic and spatial texture features are extracted from facial regions using Local Phase Quantization (LPQ) texture descriptor, robust to blur, illumination and expression variations. After the low dimensional representation of these features, a linear aging function is learned using multiple linear regression. In the experiments FGNET and PAL databases are used to evaluate the age estimation accuracies of facial regions i.e. eye, nose, mouth and chin, cheek and sides of mouth, separately. The results have shown that the eye region carries the most significant information for age estimation. Also the mouth and chin, cheek regions are effective in the prediction of age. The results also have shown that, using the spatial texture features enhances the discriminative power of the texture descriptor and thus increases the estimation accuracy.

Keywords— Age estimation, Local Phase Quantization, Facial Regions, Regression

I. INTRODUCTION

Age estimation is the process of estimating the age or age group of an individual according to his/her facial information. During the aging process, evident alterations occur on human facial appearance. These variations are personalized and affected by factors such as race, genetics, living conditions, eating habits, the frequency of facial expressions, etc. This makes the age estimation problem much harder than other facial image processing problems. Therefore the accuracy of the age estimation systems is insufficient, even the human skills about age estimation are limited. In this context, discovering the amount of aging information contained in facial regions and thus improving the accuracy of age estimation systems by using the facial regions emphasizing the aging information is an important issue in this field.

In this paper we investigate the age estimation performances of facial regions: eye, nose, mouth and chin, cheek, sides of mouth. For this purpose we designed an age estimation system using the texture features of these facial regions to produce an estimate of the age of a subject. The block diagram of the system is shown in Fig.1. In our method the input images are normalized so that the shape variations such as scale, head pose are eliminated and the facial texture is aligned. Then Local Phase Quantization (LPQ) is used to extract holistic and spatial texture features from facial regions. After feature extraction, dimensionality reduction is performed with Principal Component Analysis (PCA). Finally an aging function is learned using Multiple Linear Regression (MLR) for age estimation. The feature extraction, dimensionality reduction and aging function learning steps are performed separately for each of the facial regions to discover the amount of aging information contained in that region.

Fig. 1. System overview

The rest of the paper is organized as follows. A survey on the age estimation methods are given in Section 2. The proposed age estimation approach is explained in Section 3. In Section 4 the experimental results on various databases are reported and analyzed. Finally, the conclusions are outlined in Section 5.

II. RELATED WORK

Age estimation systems generally consist of age image representation and age estimation modules. The aim of age image representation module is to extract the shape or texture based features from facial images. Then classification techniques are used to classify the facial images into multiple
age groups or regression techniques are applied to estimate the age of the subjects.

The age image representation techniques can be grouped under five topics. The anthropometric models relays on the facial geometry. In these models the distances and the ratios of these distances are calculated using the fiducial points on the facial images. As these geometrical features can only deal with young ages, wrinkle features are used with geometric features to strengthen the classification performance for older ages [1-3]. Active Appearance Model (AAM) based age estimation methods incorporate shape and appearance information together. For this reason AAM’s are frequently used in age estimation methods [4-6]. In some studies AAM features are extracted as global facial features and fused with local facial features for efficient age estimation [7]. In Aging Pattern Subspace method, the sequence of an individual’s aging face images are used to model the aging process [8]. But age manifold methods uses the images of different individuals at different ages to learn the common aging pattern. They utilize manifold embedding techniques to discover the aging trend in a low dimensional space [9, 10]. Appearance models are mainly focused on aging-related facial feature extraction using various texture descriptors such as local binary patterns, Gabor filters, histograms of gradients etc. [7, 11-13].

All the studies mentioned above generally uses the whole face in feature extraction phases. Unfortunately the number of works examining the age estimation performances of facial regions/parts is insufficient in the literature. Lanitis [14] investigated the significance of facial parts in age estimation. In the experiments, the age estimation performances of whole face (including the hairline), internal face, upper part of the face and lower part of the face are calculated. AAMs are used to represent the shape and appearance of facial parts with model parameters. The results showed that the upper part of the face gives the minimum age estimation error than other parts. El-Dib and Onsi [15] used bio-inspired features to analyze the different facial parts: eye wrinkles (covering the eyes and the area under the eyes), internal face and whole face. They built six support vector regression and one support vector machine model to estimate the age of a subject. Their results showed that the eye region covering the eyes and the area under the eyes contains the most important aging features when compared with others.

III. PROPOSED METHOD

A. Image Normalization

In order to eliminate the shape variations such as head pose, scale, size, etc. and to align the texture information, image normalization is applied on facial images. Image normalization is performed by warping the facial images into the mean shape obtained from training set. The facial images in the training set are labelled with 68 landmark points as shown in Fig.2-a. Mean shape is obtained by taking the mean of all coordinates of these points. Then all the images are warped into the mean shape using Delaunay triangulation as shown in Fig. 2-b and affine transformation, so the landmark points of all images are matched with the mean shape and also the texture information is aligned. The result of warping process is given in Fig. 2-c. As the head poses of facial images varies, the warped images can be inclined, therefore rotation is the last step in image normalization as shown in Fig.2-d.

Fig. 2. Image normalization a) Facial image labeled with 68 landmark points b) Delaunay triangulation c) The image after warping into the mean shape d) Rotated image

B. Facial Regions

Investigating the aging information contained in facial regions is important for age estimation system’s design. In this way, the accuracies of age estimation systems can be improved by using the facial regions emphasizing the aging information. For this purpose the facial images are divided into regions and the age estimation algorithm is applied to these regions separately. In the study the age estimation performances of eye (190×55), nose (55×70), mouth and chin (85×70), cheek (65×60) and side of mouth (40×45) regions are determined. The facial regions used in the experiments are shown in Fig. 3.

Fig. 3. Facial regions a) eye b) cheeks (left and right) c) nose d) side of mouth (left and right) e) mouth

C. Feature Extraction with LPQ

LPQ is a blur insensitive texture descriptor based on the blur invariance property of the Fourier phase spectrum [16]. In this method LPQ codes are computed in local image windows using discrete Fourier transform (DFT) and the results are presented as a histogram.

The spatially invariant blurring of an image can be expressed by a convolution between the image and the point spread function (PSF). In the frequency domain this is equal to \( G(u) = F(u) . H(u) \), where \( G(u) \), \( F(u) \) and \( H(u) \) are the DFTs of the blurred image, the original image and the PSF, respectively. Considering the phase of the spectrum we have \( \angle G(u) = \angle F(u) + \angle H(u) \). If we assume that the blur PSF \( h(x) \) is centrally symmetric, \( h(x) = h(-x) \), its Fourier transform is always real valued, 0 for \( \angle H(u) \geq 0 \) and \( \pi \) for \( \angle H(u) < 0 \). This means that \( \angle G(u) = \angle F(u) \) for all \( H(u) \geq 0 \) and \( \pi \) for \( H(u) < 0 \).
0. In other words the phase of the observed image $\angle G(u)$ is invariant to centrally symmetric blur, at the frequencies where $H(u)$ is positive.

If the $N \times N$ neighborhood around a pixel $x$ is denoted as $N_x$, the two dimensional (2-D) DFT of $N_x$ is defined by,

$$ F(u, x) = \sum_{y \in N_x} f(x-y) e^{-2\pi i u y} = w_{f}^T f_x $$

where $w_{f}$ is the basis vector of the 2-D DFT at frequency $u$, and $f_x$ is the vector containing all $N^2$ pixels in $N_x$. Only the complex coefficients of $u_x = [a, 0]^T$, $u_y = [0, a]^T$, $u_z = [a, a]^T$, $u_w = [a, -a]^T$ are considered in LPQ. $a$ is a scalar frequency below the first zero crossing of $H(u)$ that satisfies $H(u) \geq 0$. For each pixel position this results in a vector given by

$$ F'_x = [F(u_1,x), F(u_2,x), F(u_3,x), F(u_4,x)] $$

$$ F_x = [\text{Re}(F'_x), \text{Im}(F'_x)]^T,$$

where $\text{Re}()$ and $\text{Im}()$ return real and imaginary parts of a complex number, respectively. Then $G_x$ is computed for all image positions, i.e., $x \in \{x_1, x_2, \ldots, x_n\}$, and the resulting vectors are quantized using a simple scalar quantizer,

$$ q_j = \begin{cases} 1, & \text{if } g_j \geq 0 \\ 0, & \text{otherwise} \end{cases} $$

where $g_j$ is the $j^{th}$ component of $G_x$. The quantized coefficients are represented as integer values between 0-255 using binary coding using (5), and the histogram of these integer values is used as a feature vector.

$$ b = \sum_{j=1}^{b} q_j 2^{j-1} $$

The LPQ texture descriptor represents the input image as a histogram of 256 bins. In this holistic representation, the histogram is produced without taking into account the spatial information of the pixels. The discriminative power of the texture descriptor can be enhanced by using the spatial histograms. The spatial histograms are produced by concatenating the local histograms extracted from small image blocks.

**D. Dimensionality Reduction**

In order to find a lower dimensional subspace of the extracted features and to obtain the significant features for age estimation, dimensionality reduction is performed using PCA. PCA method finds the embedding that maximizes the projected variance given by $W_{opt} = \arg \max_{W} \|W^T S W\|$ where $S = \sum_{i=1}^{n}(x_i - \bar{x})(x_i - \bar{x})^T$ is the scatter matrix, $x_i$ is $i^{th}$ feature vector with $x_i \in R^D$ and $\bar{x}$ is the mean of the feature vectors. By solving this problem, a set of $d \leq D$ eigenvectors associated to the $D$ largest eigenvalues of $S$ is obtained. Then dimensionality reduction is performed by projecting all samples on the projection subspace using $y_i = W^T x_i$ with $y_i \in R^d$.

**E. Age Estimation**

After finding the low dimensional representation of features, the age estimation problem is recast as a multiple linear regression as $L = YB + e$ where $Y$ is the data matrix, $B$ is the unknown parameter vector, $L$ is the age label vector and $e$ is the error vector. In the learning phase the unknown parameters are estimated by means of least squares, or robust regression. The regression function used in this study is a linear function given by $\hat{l} = \beta_0 + \beta_1^T y$ where $\hat{l}$ is the estimate of age, $\beta_0$ is the offset, $\beta_1$ is the weight vector containing the coefficients for each value in the feature vector and $y$ is the low dimensional representation of the extracted feature vector.

**IV. EXPERIMENTS AND RESULTS**

In this paper the FGNET and PAL databases are used to evaluate the age estimation performances of facial regions. FG-NET database [17] is composed of 1,002 images that were retrieved from real-life albums of 82 subjects, thus includes variations of head pose, occlusion, illumination, facial expressions, etc. The age range in this database is 0-69 years, but the images are not uniformly distributed according to the ages. This can be a disadvantage for the estimation accuracy.

The PAL aging database [18] contains 580 images of different persons taken under natural lighting conditions using a digital camera. The images include various expressions such as neutral faces, anger, sadness or smiling. The age distribution of the images in this database is between 18 and 93 years old and also not uniform.

The age estimation performance of the system is evaluated using $n$-fold cross validation method. In this method all the samples are randomly partitioned into $n$ equal sized subsamples. Then one subsample is used as test set and $n-1$ subsamples are used as training set. This procedure is repeated $n$ times until each of the subsamples are used once as a test set. Then the average of all $n$ estimations is considered as the system performance. In our experiments we set $n=3$.

The performance is measured using the Mean Absolute Error (MAE) metric given as,

$$ \text{MAE} = \frac{1}{N_t} \sum_{i=1}^{N_t} |\hat{l}_i - l_i| $$

where $\hat{l}_i$ is the estimated age value of $i^{th}$ test sample, $l_i$ is the real age value of $i^{th}$ test sample, and $N_t$ is the total number of test samples.

In the experiments the age estimation performances of facial regions are calculated using the features extracted with LPQ texture descriptor and regression. LPQ is performed on $5 \times 5$ local image windows. The LPQ histograms are first extracted from the whole facial region resulting the holistic description of that region. Then the region is divided into $n \times n$ blocks, LPQ histograms are extracted from each block and concatenated to obtain the spatial description of the region. The spatial features are used to enhance the discriminative power of the texture descriptor. The spatial LPQ histograms are extracted for $n=2, 3, 4, 5, 6$ and age estimation is performed using these features. The effect of using the spatial texture features of facial regions for age estimation on FGNET and PAL databases are given in Fig. 4. We can see from the figure that the holistic feature representation is not
encouraging and increasing the number of blocks in spatial feature representation generally increases the estimation accuracy of the facial regions.

![Graph](image)

The age estimation accuracies of the whole face and facial regions are tabulated in Table 1. We can see from the results that the age estimation accuracy of the whole face and the eye region are close to each other. These results indicate that the eye region carries the most significant information for age estimation. Also the mouth and chin, cheek regions are more effective than other regions in the prediction of age.

### Table 1

**MAE’S OF FACIAL REGIONS FOR FGNET AND PAL DATABASES**

<table>
<thead>
<tr>
<th>Regions</th>
<th>FGNET</th>
<th>PAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole face</td>
<td>5.83</td>
<td>6.94</td>
</tr>
<tr>
<td>Eye</td>
<td>6.30</td>
<td>7.83</td>
</tr>
<tr>
<td>Nose</td>
<td>8.04</td>
<td>10.24</td>
</tr>
<tr>
<td>Mouth and chin</td>
<td>7.71</td>
<td>8.46</td>
</tr>
<tr>
<td>Cheek</td>
<td>8.21</td>
<td>10.04</td>
</tr>
<tr>
<td>Side of mouth</td>
<td>8.66</td>
<td>10.52</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In this paper the age estimation performances of the facial regions are investigated. For this purpose the facial image is divided into five regions: eye, nose, mouth and chin, cheek, side of mouth. Then LPQ is used to extract features from these regions. In the feature extraction phase holistic representation of the region is obtained by applying the texture descriptor on the whole region. Also the spatial representation is obtained by dividing the region into number of blocks, extracting features from these blocks and concatenating them. The age estimation accuracies of the facial regions are evaluated separately and the experiments on FGNET and PAL databases have shown that the most of the aging information is contained in the eye region. Moreover the age estimation accuracy of the eye region is close to the whole face. As the estimation of the whole face is better than the regions alone, determining the weights of these regions in age estimation and thus achieving better estimation accuracy is our future work.

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Detection of Rail Switch Passages Through Image Processing on Railway Line and Use of Condition-Monitoring Approach

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Abstract— Today, railway transportation is one of the transport modes commonly used. Compared to other transport modes, railway traffic is highly critical. Multiple railway vehicles run constantly on one or two lines. Rail switch passages are used to prevent locomotives from colliding with one another and avoid traffic disruptions. Through switch passages, locomotives pass from one line to another. Friction between rail and wheels on switch passages is considerably high. This friction leads to failures on switch passages. Unless these failures are diagnosed early and remedied, significant accidents emerge.

In this study, a new approach based on image processing has been presented for detection of rail switch passages on railway lines. A test vehicle has been created in order to test the proposed approach and apply it on a real-time system. Railway line is monitored by digital cameras fixed on this test vehicle. Image-processing approach is developed on the real-time images captured from the railway line and the switch passages on the line are detected. The image-processing approach consists of three main parts including pre-processing, feature extraction and processing of the features obtained. At the pre-processing stage, the basic image processing methods are used. At the feature extraction stage, Canny edge extraction algorithm is used and hence the edges in the image are detected. Hough transform method is used at the stage of processing of the extracted features. Following Hough transform stage, straight lines and angles of these lines are obtained on the image. Taking into account the angle of each straight line, the junction points of the lines are calculated. Thus, rail switch passage and switch types are detected. The proposed image-processing approach is highly fast and real time-based. Compared to the existing studies in the literature, it is seen that the proposed method gives fast and successful results. This study intends to diagnose the failures on switch passages early and prevent potential accidents.

Keywords— Railway, Condition Monitoring, Fault Detection, Image Processing, Railroad Switches.

I. INTRODUCTION

Railway transportation is commonly used in the freight and passenger transport. Railway vehicles provide transportation using a particular rail line [1,2]. These vehicles are preferred by people because they can carry quite heavy loads and large number of passengers. It is very important for rails to be robust because railway vehicles provide transportation on the rails [3]. The railway lines are the most critical components for this transportation. The switch has been developed for more than one train can use the same railway line. Trains can change their direction, give way to another train or proceed to the standby points at the station due to the switch system. The development of the switch system has made the railway line quite utilizable. Therefore, the switch system has a great importance for the railway transportation. Excessive friction and wear occur during switching [4]. Such undesirable situations lead to major wear on the rail in time. Major accidents may occur in the event of failure in the early diagnosis of these wears. The accidents that may occur can cause loss of life and injury for passengers. However, the railway line hinders the traffic for a while during the accident, and major financial losses are formed. Today, the railway line is inspected at regular intervals, and the faults which may arise are diagnosed early. There are many literature studies related to switch system. Johansson et al. [5] conducted a study for the detection of the corrosion faults caused by friction and wear during switching. In the study, Switches & Crossings components are monitored. They modeled the contact of the wheel with the rail by simulation during switching. As a result of modeling, observation was made according to the loads that may occur on the rails. Boccialone et al.[6] proposed a signal processing-based method for the detection of the faults that occur on the rail surface. In the proposed method, the vibration signals made by the train while going on the railway line were used. Fault detection is performed by improving the signal processing methods through vibration signals. Palsson [7] completed a thesis study on optimization in the Switches and Crossing sections on the railways. In this thesis study, Switches and Crossing components were monitored and the faults that occurred in these components were examined. The changes in the Switches and Crossing areas were observed during switch transitions. The load distribution from one rail to another rail was examined. In addition to these studies, many studies have been conducted for the detection of the faults occurring on the rail surface and in its components. Quingyong et al. [8] an image processing based contactless method is proposed and detected faults on rails in real-time. Rail surface is extracted by using railway images. Surface faults are determined by contrast stretching of the obtained surface. This method, is used only railway surface to detect faults. Limin et al. [9]
proposed a method that detects faults on the surface by using machine vision techniques. The roughness and cracks are determined with image processing algorithms. Edge detection and feature extraction methods are used.

Ying et al. [10] proposed an automatic monitoring approach to detect and evaluate the railway components. The proposed method is working on a train with 16km/h speed. Ray component detection is carried out by applying Sobel edge detection and Hough transform methods. Status and positions of the components are observed and analysis of them is carried out. The general architecture of the proposed railway inspection system is presented in Figure 1.

Fig. 1 General architecture of the railway inspection system proposed in the literature [10]

In this study, an image processing-based method was proposed for the detection of the crossing points on the railways. Images were taken for different types of switches using a camera fixed on the train. The switch crossings were determined using image processing algorithms on the images taken.

II. TYPES OF RAILWAY SWITCHES

The apparatus for changing the way that allow railway vehicles moving on the rail to pass from one rail to another rail are called "switch". In switch systems, the change of way of railway vehicles is carried out by ensuring the movement of the Switch part of the junctions with human or electric power [11]. Each switch has a right track and a diverted track. The sleepers of the switches on conventional lines are wooden. The radius of the curve located on the diverted track that provides transition to secondary roads is R=300 m, the maximum length standard of single turnout is 34.20 m. The sleepers of the switches on high-speed trains are concrete, the radius of the curve located on the diverted track that provides transition to secondary roads is R=1500 m, the maximum length standard of single turnout is 72 m.

Railways have switch crossings for the control of the traffic and a line to be used by more than one trains. A train moving on a line can easily switch to the other line due to switch crossings [12]. An example of a switch crossing system and components is given in Figure 2.

As it is seen in Figure 2, the switch crossing system has many components. The components of Switch Blades, Toe, Stretcher and Heel serve as a switching. The components of Crossing, Check Rails and Wing Rails allow train to switch to another rail in a secure way. The components of Check Rails and Wing Rails are the most important components that prevent the derailment of the train. The switch crossings are very important on the railway line. Major faults may occur as a result of the failures of the components on the switch crossings. Therefore, the railway line especially the switch crossings should consistently be inspected. It is required to make the necessary maintenance even considering the small faults. On switch crossings, to which direction the train will go is determined using the components of Switch Blades, Toe, Stretcher and Heel. The changes that occur on the switch crossings when a train goes straight or to the right direction on an example railway line are seen in Figure 3.

In the sample images given in Figure 3, a train coming from X direction in Figure 3.a goes straight ahead, namely to the Y direction. In Figure 3.b, a train coming from X direction turns right, namely to the Z direction. There are many types of switch crossings which are commonly used on the railways. These types of switches vary depending on the number and position of the railway line. The types of switch crossings and their sample images are given in Figure 4.

The sample images of the switch crossing types given in Figure 4 are presented in Figure 5.
III. THE METHOD PROPOSED FOR SWITCH DETECTION

In this study, an image processing-based method was developed for detecting the switch crossings on the railway line. In the proposed method, feature extraction was performed by performing pre-processing on the image. The lines on the image are obtained as a result of feature extraction. The intersection points are calculated by considering the start and end positions and slopes of the lines obtained. The calculated intersection points are called switch crossing zone. The flow chart showing the main stages of the proposed method is presented in Figure 6.

In the proposed method, images are taken from a camera placed on the locomotive. The colorful images taken from the camera are primarily converted into gray format.

Canny edge extraction is performed using the gray image obtained. The edges on an image are defined as the sudden change of the pixel values on the edge zones. The edge extraction methods are very important for feature extraction in image processing applications [16,17]. Canny edge extraction algorithm is an edge extraction algorithm which is realized as multi-staged. The general steps of Canny edge extraction algorithm are as follows:

- Performing smoothing by applying Gauss filter to the image
- Performing edge extraction in the X and Y directions
- Calculation of gradient magnitude and angle
- Elimination of undesirable details and obtaining image

In Equation 1, \( f(i, j) \) represents the gray level image matrix, \( R(i, j) \) represents the red image matrix, \( G(i, j) \) represents the green image matrix and \( B(i, j) \) represents the blue image matrix. The image smoothing process is performed by applying gauss filter to the image in gray format obtained. A gauss mask in 5x5 size is used in the Gauss filter.
After the gauss masking process, edge extraction is performed by using the canny masking matrix of the image from X and Y direction. The image is formed according to certain angle limits by calculating the gradient magnitude on the image matrices obtained.

The edge extraction process is achieved more successfully because Canny edge extraction algorithm uses the Gauss filter before performing edge extraction on the image. Canny edge extraction algorithm gives better results compared to other edge extraction algorithms.

Hough transform is used to obtain the lines on the image after the edge extraction process [18]. Hough transform is generally used in detecting geometric models on the image in combination with the edge extraction methods. Hough transform is applied onto the images, the edge information of which are obtained. The method transforms the problem of finding a shape into a problem of finding a density by transferring the information in the image space to the parameter space [19-21]. Hough transform does not require that the points on the image are side-by-side or connected to detect an image. The pseudo code of Hough transform used in the proposed method is given in Figure 7.

A binary-based image obtained as a result of edge extraction is primarily used in the pseudo code of Hough transform given in Figure 7. The straight lines are expressed as in equation 1.

\[ y = mx + n \]  (1)

This equation has two parameters to specify any straight right. These parameters are slope \((m)\) and junction point \((n)\). A point in the straight lines parameter space is shown as \((m,n)\). The straight lines are transformed into coordinate system and shown in equation 2.

\[ r = x\cos(\theta) + y\sin(\theta) \]  (2)

In this equation, the nearest vector from the origin is represented by a pair of \((r,\theta)\). All lines with angles ranging between 60 and 150 on the detected lines are taken into account. The junction points of the lines are calculated using the angle values of the lines obtained and the start and end points of the line. The method of the slope of a line two points of which are known was used in obtaining these lines. The lines representing the rails are detected by considering the slope ranges of the lines on the railway image. The slope of a line two points of which are known is given in equation 3.

\[ m = \frac{B_y - A_y}{B_x - A_x} \]  (3)

In equation 3, \(m\) represents the slope, \((A_x, A_y)\) represents the location information of the A point and \((B_x, B_y)\) represents the location information of the B point. The switch crossings on the railway line are detected according to the slope value obtained by applying this equation on the gray image. Two points of each line are known. These two lines intersect and give the switch crossing zone. For the calculation of the crossing point, the required calculations were made for the junction point of the line two points of which are known. First of all, the points of the line taken from the normal image are A, B, C, and D. The junction point of these two lines is E. The junction point of two lines two points of which are given is shown in the analytical plane as in Figure 8.

In order to calculate the values of the E point given in Figure 8, another line passing from E, F, and G point is drawn. The equation of the line the slope of which is \(m_i\) is given in equation 4.

\[ m_i = \frac{G_y - F_y}{G_x - F_x} \]  (4)

By calculating the location information of F and G given in equation 4, the final state of the equation 4 is given in equation 5.
m_i = ((D_i - C_i) \times (C_i - A_i)) - ((C_i - A_i) \times (D_i - C_i))

(5)

By using \( m_i \) value given in equation 5, \( E_x \) and \( E_y \) values are calculated in equation 6.

\[
\begin{align*}
E_x &= A_x + (B_x - A_x) \times m_i \\
E_y &= A_y + (B_y - A_y) \times m_i 
\end{align*}
\]

(6)

The switch crossing zone is detected on the image using \( E_x \) and \( E_y \) values obtained in equation 6.

IV. EXPERIMENTAL RESULTS

In this study, an image taking environment was created to take sample images on the railway line. The images of the railway are taken by the camera installed on the train as in Figure 9.

Fig. 9 The test vehicle used to take image

In the proposed method, the switch crossings were detected by taking images in different situations on the railway line. The dimensions of the images taken are 640 x 480 pixels. The color image was firstly transformed into gray image, and then edge extraction was performed. The lines are obtained by Hough transform on the image obtained. The images used during realization of the proposed method are given in Figure 10. The results were obtained by performing edge extraction on the image given in Figure 10. These results are presented in Figure 11.

Fig. 10 The images belonging to different types of switch crossings taken from the railway

![Fig. 10](image10.jpg)

a) b) c) d) e) f)

Fig. 11 Performing feature extraction by applying edge extraction on the image
The edge extraction results of different images are presented in Figure 11. After the edge extraction process, Hough transform was used in order to detect the lines on the image. The lines were detected by taking into account the angle value and the positions of the line during Hough transform. The switch crossings were detected by improving a method on the lines detected. The result of detecting the switch crossings on the sample images is presented in Figure 12.

![Detection of the switch crossings on the railway line by Hough transform](image)

As it is seen in Table 1, the proposed method is highly successful in the images belonging to the types of single left and right switch. The success ratios of other types of switch are not very good because they are a little more complicated and due to the clarity of the image.

### V. Conclusions

An image processing based method for the detection of railway switch crossings was proposed in this study. In the proposed method, the switch crossings were detected by image processing methods using railway images. Canny edge extraction and Hough transform were used as the image processing methods. When the studies in the literature are analyzed, it is seen that there is not a study on the detection of switch crossings and condition monitoring by using image processing based methods. It is seen that the proposed method is successful when its results are taken into account. However, different methods will be used in future studies to make study more qualified and successful. In addition, the detection of the faults occurring in the components on the switch crossings and the detection of the rail surfaces on the switch crossings are aimed in future studies.

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Trust in Wireless Sensor Networks

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Abstract—Wireless sensor networks are used widely in daily life. With that increase the problems faced in WSN usage have become more interesting for the research community. The problems that outstand the most are related to the trust and energy issues. As wireless sensor networks have limited energy and computing power, cryptographic algorithms are not suitable for these type of networks. Along with that line, in this work we explore trust models developed for wireless sensor networks.

Keywords: Wireless Sensor Networks, Trust, Trust Models

I. INTRODUCTION

Trust is quite important for self-configurable and autonomous systems such as WSNs [15]. WSNs are very vulnerable environments due to computational limitations, energy constraints and network attacks. In addition, WSNs are very open to physical world effects such as a person walking on a field can step on a sensor and make it dysfunctional. A trust management scheme can make a WSN tolerant to node failures and misbehavior by assisting decision making process. For example, a node can decide to cooperate with a node or not based on the feedback it will receive from the trust model. Trust research on WSN is very new, few systems have considered it [17], [45]. More research has been done on Trust in Ad-hoc and P2P networks. Although these network types have many similarities to WSN, still a separate trust management system has to be developed for WSN because of their specific characteristics such as energy and communication constraints.

Data collection is very important in the process of designing a trust management system. The system should be history aware, past behaviors should be taken into consideration [15]. WSNs should be history aware as the trust calculation is considering past behaviors. Moreover, every node keeps their past behavior statistics regarding the data they produce such as average error of the created data in the past time intervals. One of the biggest constraints is the overhead that can be caused by the trust model. Trust model should be as lightweight as possible [15].

There are many different data that can be used as input of the trust model. For example, a node that is not alive for a long time or a node that appears or disappears randomly may not be trusted. On the communication layer, a node which is misreporting will not be trusted. For instance, a node which is giving a fire alarm when conditions are calm should be given a low trust value [15].

II. DEFINITIONS: TRUST, TRUSTWORTHINESS, RISK, REPUTATION

Josang et al. [20] define trust and trustworthiness based on the definitions of Gambetta [16]. Solhaug et al. [39] define trustworthiness as objective probability that the trustee performs a particular action on which interests of the trustor depend. Trust is a subjective probability varying from 1 (complete trust) to 0 (complete distrust) [20].

As trust is the believed probability and trustworthiness is the actual probability, there can be a difference between them. This difference introduces the risk factor [12]. Risk increases if the trust is misplaced.

Reputation is also a concept that is very related to trust. Sometimes reputation and trust is used in the same context however they have different meanings. Reputation is the opinion of an entity about the other entity. However trust is derivation of reputation of an entity.

A. Information Trust

There are different types of trust such as social trust, cognitive trust, and communication trust. In this work, we are assessing the information trust of data items and sensor nodes.

Information trust or data trust refers to the trust placed on data produced by objects or processes. Information trust in a network is important because it can prevent erroneous data to accumulate in the network. In a network, a node can (i) create data (ii) process the data such as fusion (iii) pass the data along. The trust of data depends on the trust of the node that creates the data and the trust of the nodes the data has visited. Information trust in a network can be categorized into three: (i) creator node’s subjective view of the trust (ii) objective trust assessment of the data by the neighboring nodes (iii) changes in information trust as the data travels along the network.

B. Properties of Trust

Cho et al. [12] list characteristics of trust as follows in their survey paper.

- dynamicity : Due to node failures and mobility, sensor network is highly dynamic hence trust should be dynamic too.
- subjectivity : Nodes might decide to put different levels of trust on same nodes due to dynamicity of the network [1].
• transitivity: Trust is not necessarily transitive. For transitivity, we need two types of trust, trust in a trustee and trust in recommendations of the trustee.
• asymmetry: Trust is not necessarily transitive. A node may trust a node however the trustee node may not trust the trustee.
• context-dependency: Trust is context-dependent [7]. For instance, a node may trust the image data coming from a node but may not trust the audio data coming from the same node.

III. TRUST AND REPUTATION IN DIFFERENT DOMAINS

Below we give information about trust literature in social science, e-commerce, distributed systems and ad-hoc networks based on the survey of Momani and Challa [27].

A. Trust in Social Science and E-Commerce

Trust is very related to social sciences because it is a part of human life [38]. It has a very big impact on human relationships such as making friends, sharing secrets, selling/buying things, working together. It eases the everyday life by helping in the decision making process, delegation, certification, resource access [36].

One of the motivating domains for trust research is e-commerce. In internet, buyers and sellers have a trust relationship. Buyers will buy from sellers that they trust. The trust will be formed based on the reputation of the seller. Seller gains a reputation based on past behavior. E-commerce systems such as eBay [35], Yahoo [35], Keynote [8], [9] keep a centralized trust authority to maintain the reputation and trust values.

Abdul-Rahman and Hailes designed a trust model based on sociological characteristics of trust [3]. In their model, entities are given trust based on their reputation (indirect) and their direct experiences. They also consider the word-of-mouth mechanism. Agents put different importance (weights) to opinions of different agents.

Josang and Ismail developed a reputation system for electronic markets [21]. Most reputation systems are intuitive and ad-hoc however they have built their reputation systems on beta probability density function in statistics. The beta distribution is mapped to an opinion, which is a belief about the truth of statements.

B. Trust in Distributed and Peer-to-Peer Systems

In distributed systems, there is no central authority for assessing the trust of entities. Hence entities form their own opinions of trust by exchanging information with their peers. Generally methods from game theory [44], bayesian networks [43] are used for trust calculation distributedly. Aberer and Despotovis were one of the first researchers to propose a reputation management system for P2P systems [4]. They employ algorithms and data structures that require no knowledge from a central authority. The trust model is based on the past interactions between the nodes. One drawback of their method is that only the negative feedbacks are considered and the system is sensitive to misbehavior of peers. The resurrecting duckling model in [40] and its descendants [6] use out-of-band channels to authenticate key exchange. The established trust between the nodes is binary, either secure or not secure.

There are other trust models for peer-to-peer systems which we do not want to go into details of as we are interested in trust models for sensor networks. Other trust mechanisms surveyed by Momani and Challa [27] are SECURE[11], Distributed Trust Model[2], Bayesian Network Model [43], UniTec[22], BambooTrust[23], B-trust model[34].

C. Trust in Ad-hoc Networks

In ad-hoc networks, nodes join to networks or move networks very often. There are no trusted nodes to support the network functionality. Trust relationship between the nodes is also dynamic as the network is constantly changing [46]. A majority of the trust mechanisms in ad-hoc networks use game theory and bayesian network approaches. Two examples of these systems are CONFIDANT [10] and CORE [26].

IV. TRUST IN WSN

There are some surveys done on trust in WSNs [5], [15]. WSNs face different kinds of attacks such as eavesdropping, fabrication, injection, modification of packets, node capturing and many others [27]. These attacks raise issues such as privacy, accountability, data integrity, data authentication and data freshness. Some research has been done on security of WSN as surveyed by Momani and Challa [42], [30], [46], [41], [28], [48], [31], [40], [47], [33]. Cryptographic mechanisms do not completely solve the problems. System faults, erroneous data, bad routing by malicious nodes can cause network breakdowns. Cryptography is not sufficient to solve the security problems, cryptographic approaches should be integrated with tools from domains such as statistics, e-commerce, social sciences. Some nodes can behave maliciously or selfishlessly. Trust architectures have to discover and isolate these nodes. There are different approaches followed by researchers [46].

- Maintain a trust and reputation table for all nodes in a sub-network
- Use a watchdog mechanism to monitor the behavior of the nodes
- Discover faulty nodes and exclude them from the network
- Reward nodes so that they comply with protocol rules
- Use of low-cost cryptography to protect the integrity of the data

Trust has been researched for a long time [25]. It has been studied by many disciplines such as social sciences [37], economy [13]. Yet we cannot say that there is a formal definition of trust. Trust establishment between the nodes is a security approach that is very effective in WSNs. As nodes work cooperatively, trust relationship between them improve the security of WSN.

Security and trust are very related concepts and sometimes they are used interchangeably [32]. However security is
different than trust. It is broader than trust and overhead is higher in security.

Trust is used in restructuring WSNs such as omitting nodes, adding nodes, merging clusters. Trust establishment is a must because WSN depends on cooperative and trusting nature of its nodes. However due to limited resources in WSN, it is not possible to use the traditional cryptographic approaches [14]. Different trust mechanisms are needed for wireless sensor networks. Trust in WSNs is still an open and challenging field.

A. Best Practices of Trust in WSNs

Lopez et al. describe the best practices of trust management in WSNs in their survey [24] based on the other surveys [15], [19], [18].

B. Trust and Reputation

Reputation and trust should be maintained separately in a WSN. Reputation builds in time. To make an accurate decision, trust should be calculated based on reputation. Without reputation trust will have a value based on the instant behavior. For instance, a node that has behaved maliciously in the previous 10 time intervals can behave good, however the network will not be deceived by the last action as the reputation will reflect the bad behavior history.

C. First-Hand Information Gathering

There are many events in a sensor network that can be used as a base for trust computing such as hardware errors, energy issues, node relocations, sensor reading deviations. These are considered first-hand information and they should be taken into consideration. A trust management system that considers multiple sources of information will be more robust.

D. Second-Hand Information Gathering

As sensor networks consist of nodes that are working collaboratively, second hand information should be considered for trust management. A node can have local intelligence. To some extent it can detect abnormal activities of itself and can report this to its neighbour nodes. It can also report a bad behavior of its neighbor to another neighbor. However when considering second hand information, we should be careful about bad mouthing attack. Bad mouthing attack happens in WSNs when a node gives bad reports about a good node and good reports about a bad node misleading the trust calculation.

E. Initial Values

The nodes in the network should be given initial trust values at the deployment time. As we assume that a network administrator has configured them and tested them, they should all be equally trusted. However the system should be suspicious about the nodes added to the network after the deployment, as they can be part of a white-washer attack, where a node throws away its bad reputation by creating a new identity.

F. Granularity

Nodes in a wireless sensor network might have different actions such as sensing, routing. Different trust values should be assigned to different actions of a sensor node.

G. Updating and Aging

Trust should build overtime. When trust of a node is updated, the past trust values should not be overwritten. The previous trust state of the network should be remembered. If bad behaviors are not remembered, the network will be vulnerable to on-off attacks [29].

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A Review of Automatic Text Summarization

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Abstract — Giant information is available on the digital environments. Due to it has hard to get the information what you want to achieve it, fast and most efficiently. For example, if a researcher has a summary of the literature about a topic, this will be much shorter than the duration of the research. From this perspective, automatically occurring the summary of any text, it is very important for those who want to be informed. Text summarization is the compression of large document. This paper presents a review of automatic text summarizations’ approaches, studies, software, algorithms, and methods which is written by English, Turkish and some other languages in the last decades. Automatic text summarization is generally divided into two systems. There are extraction based summarizations and abstraction based summarizations. Firstly, extractions summarization approach involves selecting sentences of high score from the document based on word and sentence features. In short, finding the most important sentences from text is performed. Secondly, it is examined the semantic relationships between words and sentences in abstraction approaches. The most important difference from the first approach, made semantic analysis of words and sentences afterward new words are obtained. Mostly, optimization algorithms, genetic algorithms, fuzzy logic systems, machine learning, graph trees, statistics and probability techniques are used in automatic text summarization systems.

Keywords—Semantic analysis, text Summarization, natural language processing

I. INTRODUCTION

The development of technology with increasing speed has brought about textual data in digital cases. Under these circumstances attaining the desired information in textual data has become in terms of time. The desired textual data will be regarded as successful in terms of time expense if it includes fewer sentences alongside with useful information. This subject is crucial as for the usage of effective time consuming, has led to studies about the solution of the problem.

The fact that a sentence has been cleared of unnecessary words and sentences can be possible by means of a successful summary of that text. The aim of this review is to provide information about strategies developed and studies conducted for successful summarization. What I paid importance to while informing has been putting more emphasis on the studies carried on after 2000s. While technology and communication tools are improving rapidly, researches have come to the point of communicating more easily has been the reason for this. And at the end of this some standards about summarising studies are being developed. They have employed success measurement softwares and summary of data sets so that they can be of help in evaluation and increase of success. Another aim is the awareness of scientists who are to study on this subject.

This review consists of 3 parts. The definition of summarization and what kinds of strategies have been used will be explained in the first part. Information will be provided about summarising strategies in the second part. Some strategies will be provided about how summarising affects the evaluation of success in third part.

II. SUMMARIZATION AND APPLICATIONS HELPFUL TO SUMMARISING

A. Summarization

Text summarization can be defined as a process, which takes a text as input, includes the most important context and replaces the original and is shorter [1]. One or more textual equipment which are desired to be summarised as an input for system are provided and in the end a comparatively shorter text is provided as the summary. With this transaction a text is given to the computer programme and a summarily text which belongs to the input and includes its most important content as the output.

The emphasis of only the crucial content of a text to be summarised is called summarization process. What should be paid attention here is to determine what the content is. The content which is relevant to the topic is regarded important.

Majority of the researchers dealing with text summarization have focused on summarising the texts in English language. Therefore these studies which have been done according to grammatical structures of English language cannot be directly applied to Turkish summarization methods due to the latter’s grammatical and structural differences from of the former. For instance some structural methods where there are strong meanings of the text are free from language. Semantic analyse methods in which methods such as parsing and natural language operation are employed however cannot be used in Turkish text summarization.

A number of distinctions have been done in literature for text summarization. For example, choosing the important sentences and translating them without making any difference and evaluating this under another title is called summarising based on extractive. Another one is to comment the content from a text and rewrite it in shorter and new sentences and this method is called summarising based on abstractive. Summarising studies based on abstractive require the employment of natural language operations and detailed examination of the equipments. In abstractive based methods various parsing algorithms are used. In Turkish the by adding derivational affix to a word a parsing word is formed and by
eliminating the inflection from a word and thus finding the main word is called stemming [2]. In order to help the methods used in summarization there are a great number of other applications. Some of these are dividing a full sentence into its components, analysis and morphologic analysis (finding the stem of word, suffixes or prefixes) [3]. For instance words can be eliminated to their stems and therefore now words can be formed.

Researchers have developed softwares so as to determine the adaptive relations between words and division of words. In this part brief information about some these softwares will be provided.

B. Species of Summarization

Contrary to the abstractive based summarization, extractive based summarizations are handier and more common. Summarising without being bound to any particular word and just using some key words is called general summarization system. Summarizations limited to questioning the content is called inquiry based summary system. There are classifications based on the number of the sources of the text. In this case summarization is divided into two groups as either one document source or multiple documents. Single document based summarization, is the one whose input is a single textual data, whereas the multiple documents based summarization is the one which gets multiple documents as input, evaluates them, deals with the important parts and brings together the similar information in them and eventually summarises them on a single document. Alongside with all these groupings the document to be translated might be written in one or more different languages. Some of these approaches, represent documents to be translated with both semantic features and some structural features which enable sentences to be stated through sentence scores functions belonging sentences’ importance level.

1) Zemberek: Zemberek is open coded NLP (natural language processing) libraries which can basic NLP such as decoding, spell checking, back formation written for Turkish and other Turkish based languages. Due to its being open-coded and unignorable feat it possesses an important position among the natural language transactions. Many researches have employed Zemberek while studying Turkish summarization methods [4]. Researches have quite often used Zemberek in their studies on decoding which reveal the parsing and stem of words. In terms of structure Zemberek, consists of two parts as detailed language transactions and language structure information. The library mainly includes the softwares necessary for detailed language transactions as well as structures including stem and additions. It also contains XML libraries, which have extra information about other Turkish based languages for extra information. The additional function specially in accordance with algorithms those are sensitive for special cases. There is also a unit which controls voice cases such as sound falls, softening and assimilation. To enable these graphs tree algorithms are used. Zemberek has the ability of processing 12000 words simultaneously [4]. Zemberek, used as a tool in Turkish summarization studies is of rather high importance as an assistant. Researches use Porter Stemmer algorithms [5] to decode words in English texts.

2) Wordnet: For those researches who want to use the semantic relation between words, Wordnet [6] synonym dictionary, which define the correlation between words is a significant tool. Wordnet came about in 80s, was developed to 3.0 in 2006 and includes 155,287 words in English. For the researches working on summarization subject of Wordnet, it is of great importance that it includes a word group consisting of synonyms. The synonyms are correlated in the dictionary. Birant, in his study [7], has developed software which does summarization on its own for Turkish language as well as a dictionary of the semantic relation which he employed in his study and he has also argued that he has improved some natural language transaction tools. The two dictionaries; synonym and close-meaning dictionary and opposite meaning dictionary that he has provided in his study, have been approved by Turkish language constitution. The text summarization system based on rules which he has developed has given out results similar to those of others. In another study [8] in which sentence purification for Turkish text summarization techniques were used, methods of finding the stem of word were used as well. In this rule-based study in which syntax features are used rather than structural features, omitting letters from the end of words technique has been successfully used. In the same study the success of techniques which shorten sentences and divide sentences into shorter and multi-meaning sentences.

III. STUDIES ON SUMMARIZATION

The majority of studies on summarization are in English language. The first studies regarding textual summarization was around 50 years ago and for English texts. Although numerous newer techniques for various problems have been developed, still the traditional techniques are employed in the present and most of the problems. The reasons for them to be used are their being simple, successful, efficient and low cost. The methods requiring abstractive and natural language processing, cannot enable the methods developed for English being employed for Turkish too due to Turkish language’s suffixes structure. We can list the studies done on summarization under two general headings [9].

Extractive summarization (summarization with sentence selection) approaches are to select sentences from a text according to various techniques and combining them into a meaningful text so as to get the summarization. These methods are also called extractive methods. Another approach is abstractive summarization. In which parsing, natural language transaction techniques are used and analysing words in details, brand new words are emerged contrary to sentence selection method. For example instead of this sentence “Selim checked the menu, asked for his meal and ate” the following sentence can be used as ”Selim enjoyed his meal”. A rich symbolic list of words is necessary for this method to be used [10].
A. Extractive summarization Studies

The main focus of sentence selection technique summarization is the presence of the sentence which is regarded of vital importance. How will be the decision of whether a sentence is important? The answer to this question is significant in determining the success rate of the sentence selection summarization technique. In studies prior to 2000s, it has been decided that some sentences were far more important than others and thus be secluded from others according to a grading key. In these techniques simple but effective deductions are present. The thing that is desired to be emphasised is used more often. For example if the innovations in the field of technology are mentioned, the word technology will be used more often and the sentences in which it is present need to be present in summarization. Here, the point which should be kept in mind is that the conjunctions such as and- or – but - which are used in daily life conversations, don't in fact represent a content. This method called word frequency was used by Luhn in his study [11].

The name of this method is frequency of the word. Luhn used this method in his study. In addition that, Edmundson claimed in his study [12] that a summary must contain sentences which included some words such as "as a result", "in summary" etc. Edmundson gives more points sentences like these. This method is known as clue words phrases. His other idea is that give more point sentences that contains introduction and conclusion paragraphs. This method is called as sentences location. Also, sentences that contain the words in a title and subtitle are important according of Edmundson’s thought. The name of this method is title method.

Knowledge of date, history, arithmetic, numeric character, location, titles words, positive and negative words phrase are show importance of a sentences. Yeh et al. [13], Hernandez and Ledeneva [14] and Quyang et al. [15] have used this feature in their studies.

Study of Altan [16] is the first study on Turkish texts. He has used for data sets which written 50 document in financial issues. Firstly, he has separated heading and paragraphs using by HTML tags. Then, he examined word frequency, sentences location, words in a title, positive and negative words phrase techniques in his study.

Kılcı et al. [17] have examined date words, key words phrases, punctuation marks and proper nouns as addition to working Altan. Weighting of the sentence has already been entered in their study.

Pembe [18] has carried out query based summarization system for using web search. Then, she has given score to sentence and chapter.

Distinguishes the work of alien Çığır et al. [19], scoring was normalized. The position in the sentence of the text has been examined in this study. It was also examined according to central position of sentence.120 document is used as text data set.

We have explained structural feature of language up to now. We have seen methods of finding some most important sentences in a text. Then found sentences are rated. There are techniques combined these methods in the literature.

Suanmali et al. [20], Babar and Patil [21], Kyoomarsi et al. [22], Binwahlan et al. [23] used fuzzy logic technique for combine these methods. Silla et al. [24], Witte et al.[25], Berker and Gündör [26], Filatova et al. [27] and Mcdonald [28] have rated the important sentences with heuristic, genetic and Swarm-based optimization algorithms in their studies.

Alguilev et al. [29] have tried to solve summarize problem with nonlinear programming method. Svore et al. [30], Wong et al. [31] have used to learning machine, Bayesian classifier, support vector machines, artificial neural networks techniques. Agrawal and Gupta [32] have used the similarity of sentences to each other. For this, the K-means method is used. In the work of Seimberger et al. [33] and Orasan [34], utilizing the semantic relationships between words cohesion-based techniques are used. They have benefited from the Wordnet. D'avanzo [35] has carried out a study that knows the name of the entity and finds multiple words and based on supervised learning in his study.

We have also seen event-based methods in summarization studies. Liu et al. [36], Filotova et al.[37] examine the events in the text with the help of causality techniques. An event-term graph is obtained. The same event terms are grouped.

Uzundere et al. [38] have examined 13 different features in their study. According to this;

- Head: The words are listed in the titles and subtitles. Sentences are checked whether they have these words.
- High Frequency: Holding the number of repetition of all words in the text is created. List is sorted in descending direction. Would not include frequently used words in everyday like "and", "but", "or" etc. in this list. Words are included in summary according to determined by a percentage. Percentage is determined by the genetic algorithm or heuristic methods.
- Location: Paragraphs of sentences is determined like which sentence in the introductory paragraph or conclusion paragraph.
- Key Words: Important words for the user entered previously. Sentences that contain these words are important. For example, rebound is important word about a sport text.
- Uppercase: Special names are pure information. It should be included in the summary.
- Positive Words: More points are given to sentence which contains some word phrase like "as a result", "at last" etc. in the text.
- Negative Words: Sentences containing details are given less points.
- Collocation: Words that reinforce the meaning is considered important.
- Numbers: The score of sentences containing the numerical is high.
- Quotation Mark: Sentences including quote is important.
- Ending Mark: Punctuation mark at the end indicates the importance of a sentence.
- Average Length: The mean number of words in the text is calculated. Nearest to average sentences is considered important.
• Day-Month: Sentences including knowledge of day and month are important.

In this study firstly text is divided into sentences and paragraphs. Zemberek is used in the separation process. Then allocated structures examined designated by 13 features. Heuristic method has been used for scoring. Weighting of sentences are shown in Table I.

<table>
<thead>
<tr>
<th>Features</th>
<th>Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>20</td>
</tr>
<tr>
<td>High Frequency</td>
<td>10</td>
</tr>
<tr>
<td>Introduction</td>
<td>20</td>
</tr>
<tr>
<td>Conclusion</td>
<td>2</td>
</tr>
<tr>
<td>Uppercase</td>
<td>3</td>
</tr>
<tr>
<td>Positive Words</td>
<td>15</td>
</tr>
<tr>
<td>Negative Words</td>
<td>-20</td>
</tr>
<tr>
<td>Collocation</td>
<td>4</td>
</tr>
<tr>
<td>Numbers</td>
<td>3</td>
</tr>
<tr>
<td>Quotation Mark</td>
<td>2</td>
</tr>
<tr>
<td>Ending Mark</td>
<td>2</td>
</tr>
<tr>
<td>Average Length</td>
<td>10</td>
</tr>
<tr>
<td>Day-Month</td>
<td>5</td>
</tr>
<tr>
<td>Key Phrase</td>
<td>8</td>
</tr>
</tbody>
</table>

For example, a sentence has two key words and three numerical characters in text. Total score of the sentence is $2(2*8) + 3(3*3) = 25$. Each sentence score is calculated. A rate is asked by users. This is called summarization percentage rate. Sentences are select according to this rate. For example, if summarization rate select 35 percent, 35 percent of the sentences of highest scores would select. Then, have been tried at different rate. They have taken an average and measured to success 55 percent in their study.

In another study [39], summary of Turkish web pages has been being studied. Sentence selection is determined by 12 different features. Heuristic method has been used for weighting. Success rate was measured as 59% in this web-based study.

In a study [40] that used a combination of text and sentence clustering techniques, similar words and documents are clustered. The highest frequency sentences have been selected in this cluster.

Pointed out that in another study [41], the information in the text is obtained in two stages. In the first stage, tagged sentences are separated according to certain rules. Word phrases, word frequency, and location methods were used with modal verbs in the second stage. This study was carried out for English texts. It has benefited from the tense of the sentence to filter the information.

Extractions summarization approach was used in a study carried out in 2014. Güran at al.[42] have argued that adding a new criteria for Extractions summarization system. Name entity recognition method was used for the first time.

In a thesis published in 2014, Attokurov [43] has claimed that the main purpose of text summarization systems is to prevent the repetition of information. Optimal Tree Pruning algorithm and HAC (Hierarchical Agglomerative Clustering) algorithm are used together to prevent the repeat of information. HAC was used for extraction to repetition. Optimal tree pruning algorithm has also been used to reduce repetition.

To solve the problem of summarization have also been used optimization algorithms. In a study [44], ant colony optimization algorithms, particle Swarm optimization, artificial bee colony algorithms and genetic algorithms are used to extract more effective summary.

B. Abstractive Summarization Studies

To good determine the relationship of word-event and grouping of terms in the event tag is very important to emergence of the meaning in a text. Based on this idea, success of summarization was attempted to increase with linear algebra methods. This method is briefly performed in the following:

Primarily text is divided into words and sentences. Then a matrix of term-sentence is obtained. Matrix is factorized. After that words and phrases are converted into linearly independent vectors. Words and phrases are grouped as semantic by these vectors. Important words and phrases are selected grouped with semantic matrix factorization. After this process, semantic analysis of texts is performed by methods of Latent semantic analysis or probabilistic semantic analysis.

Murray et al. [45], Steinberger et al. [46], Yeh et al. [13] have used latent semantic analysis in their studies. Lee et al. [47], Mashechkin et al. [48] and Güran et al. [49] have also used non-negative matrix factorization (NMF) algorithms.

Güran, in her study [50] has determined sequential words with the help of Turkish Wikipedia links. In Güran's study [50], structural and semantic features are used together.

A hybrid system that combines structural and semantic feature has been proposed in order to determine important sentences. The results of hybrid systems have been more successful than each individual system. The new techniques used in stage of creating term-sentences matrix have been explained. These techniques are based on location the words and importance of words in sentences to which they belong. Study has also produced to use two new data sets for next studies on Turkish language. The first one is 130 news document, second corpora is 20 shorter text news.

Bhandari et al. [51] Chris, H. and Ding, Q. [52] have used probabilistic latent semantic analysis in these studies.

In another study [53], Non-negative Matrix Factorization methods were used to determine the relationship between sentences. Clustering and clustering methods were used in text pre-processing. The study has also been highlighted to increase quality of summarization of clustering methods.

We continue to examine studies that using method of semantic analysis. Gong and Lui [54] have divided text to topic and they have chosen sentences from each topic. In contrast, Murray et al. [45] has chosen multiple sentences...
from each topic. Özsoy et al. [55], have proposed to eliminate the noise. They have also chosen all topics in text.

Özsoy et al. [55] have proposed two new methods in studies of semantic analysis named as Cross and topics. Topics method was used to separate main subjects from sub-subjects and make sentence selections from main subjects. Cross method was also used for observe whether sentences are important. Cross-method has produced more successful results.

There is a method that shows the interconnectedness of words named as word chains method in the literature. Berker [56] has benefited relationship between words in her study. Word chains were formed in this study. Then this deep knowledge was combined with a higher level analysis. Finally, this information at different levels is combined with the help of genetic algorithms.

In a study conducted in 2010 [57], a software has been developed named as FRESA (Framework for Evaluating Summaries Automatically). This software is content-based and it make summary assessment. A system which generic single-document summarization in French and Spanish and focus-based multi-document summarization in English was introduced in study. System performance is measured by assessment package ROUGE. ROUGE Package will be discussed later.

In another study called ARTEX (Another TEXt summarizer) [58], document vectors and lexical vector are kept. In order to rank sentences, a simple inner product is calculated between each sentence, a document vector (text topic) and a lexical vector. Highest ranked were combined. No ruled-based linguistic post-processing and based in sentences extraction on Vector Space Model (VSM) techniques have used. Ranking were normalized. Each sentence is calculated in the feature matrix format. The most important aspect of this study is not requires linguistic knowledge or resources. Study is tested on French and Spanish document and it has produced successful results.

In another project [59] that using latent semantic analysis techniques have presented it presented to comparison of different vector space model. Success was measured by Ngram assessment methods. Study has proved binary models more successful than complex term frequency models.

Looking at statistical distribution of words as semantically, language processing problems can be solution. In a study [60] carried out in this thought, firstly meaning the relationship between words was measured. Meaning of integrity and key phrase extraction using lexical chains has been used. This method requires more prior knowledge. In study, has been investigated the effect of the use of lexical cohesion features in key phrase extraction, with a supervised machine learning algorithm. Studies have shown that lexical cohesion based features improve key phrase extraction. Achieved good results, compared to some other lexical cohesion based algorithms.

M. Cakir and E. Çelebi have presented a method that includes all languages to summarize their works [61]. C3M (Cover Coefficient-Based Clustering Methodology) algorithms were used. Sentences are determined with the help of similarities between sentences. Success was measured by Rouge assessment package. Successful results were obtained. Dependency grammars has been used some problems that finding similarities between sentences. The usage of dependency grammars to compute sentence similarity has been proposed in a study [62]. This study have been achieved that dependency grammar representations of sentences find out to better results in finding the similarities between sentences. Details can be reached on [62].

Most studies in the literature have been made for summarization of English language. Studies for other languages are less. Therefore, minority of studies for written on Arabic language have been emphasized in a study [63]. It has also talked about the lack of Arabic language summarization standards. It has been mentioned that Arabic was included in TAC 2011 MultiLing Pilot and ACL 2013 MultiLing Workshop. Other methods of extraction summarization studied on Arabic in the literature has been presented and grouped on a table.

IV. MEASURING SUCCESS

In order to test the success must be we should have ideally summary. In study by Rath et al. [64], people have been requested to select sentences which could be important according to them from different at different times. Güran [50] has asked to select important sentences from some people. Thus Ideal summary was obtained. In another study [65] Morris, Kasper and Adams have suggested a method named as GMAT (Graduate Management Admission Test). A technique of answering questions which exercise of reading comprehension is recommended.

Success is evaluated by various methods. To compare Ideal summary with the summary created by the system is the most known method. In order to measure success such as information retrieval, text categorization and question answering are used. The most common methods in the literature are precision/recall/F-score, value of relative benefit, cosine similarity and ROUGE.

A. Value of Precision-Recall-F-Score (PRF)

The purpose of this method is to find the number of common sentences between ideal summary and measured summary. The number of common sentences is divided to number of measured sentences. This is called precision (P). Recall value (R) is found by dividing number of common sentences to number of measured sentences. The harmonic mean of P and R is F-score (F). Formulas are shown below.

\[
P = \frac{|S \cap T|}{|S|} \quad R = \frac{|S \cap T|}{|T|} \quad F = \frac{2PA}{P + A}
\]

B. Value of Relative Benefit

This method has been proposed to correct deficiencies in PRF method. In Dragomir's study [66], sentences are rated heuristically. This is called utility score. Each sentence is rated. People are rated the sentences. "N" is number of people
and \( n \) is number of sentences in the following formula. \( Xi \) is shown \( i\)-th assessor and \( j \) is shown number of sentences. \( U \) is shown score of utility. Can be accessed for details of study here [66].

\[
Utility = \frac{\sum_{i=1}^{n} \delta_i \sum_{j=1}^{N} u_{ij}}{2 \sum_{i=1}^{n} \delta_i \sum_{j=1}^{N} u_{ij}}
\]

C. Cosine Similarity

Formula of another measurement method is given below. \( x_i \) is word frequency value at ideal summary. \( y_j \) is also word frequency value at measured summary. Can be accessed for details of study here [67].

\[
\cos(X,Y) = \frac{\sum_{i} x_i y_j}{\sqrt{\sum_{i}(x_i)^2} \sqrt{\sum_{j}(y_j)^2}}
\]

D. Ngram Statistics

Rouge (Recall-Oriented Understudy for Gisting Evaluation) software which a Ngram based technique was proposed in 2004 by Chin-Yew Lin [68]. It is produced by the Perl programming language and was used in DUC [69] (Document Understanding Conference) firstly. It is a method that based on comparison of the number of common words. There are five different measurement methods. There are ROUGE-N, ROUGE-L, ROUGE-S, ROUGE-W, ROUGE-SU and ROUGE-N. Ngram is number of 5-length sequential word group. ROUGE-N is number of common Ngrams between ideal summary and measured summary. It is calculated by the following formula. Can be accessed for details here [68].

\[
\frac{\sum_{\text{sentence groups}} \sum_{\text{gram sizes}} \text{calculate}(\text{gram sizes})}{\sum_{\text{sentence groups}} \sum_{\text{gram sizes}} \text{calculate}(\text{gram sizes})}
\]

IV. CONCLUSIONS

In this review, we have presented definitions, methods, approaches and studies about of Automatic Text Summarization. We have detected that studies was focused on English language. We have seen the success of Turkish studies around 50%. We have concluded that combination of techniques have been more successful.

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A Review of Multi Objective Optimization

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Abstract— Merging systems, enhancing inter-disciplinary relations and increasing needs require multi objectives rather than a single objective in the optimization problems nowadays. However, the objectives are frequently conflicting. When an objective is improved, the other objective(s) may deteriorate. In the multi-objective optimization problems (MOOPs), the aim is to come up with the best solutions that can be an alternative for each other in terms of objective function values under the constraints caused by various reasons. During the last two decades, MOOPs and solution methods have been studied with great interest. It is possible to come across a MOOP in almost every discipline in the literature. MOOPs have been modelled and solved not only in the fields with more applications such as production, management, business administration, marketing, transportation and finance but also in the basic sciences such as chemistry, maths and statistics. Solution of MOOPs requires the simultaneous optimization of conflicting multi objectives. In MOOPs, an optimal solution set on which a compromise is reached among the conflicting objectives is obtained. In this study, the articles on multi-objective optimization written in 2015 and later are analysed and 61 articles are chosen among them. Classical and heuristic methods implemented for the solution of MOOPs presented in these articles are mentioned. The articles are classified according to their subject areas. The methodology used in each article is identified. According to their implementation areas, the multi-objective optimization methods and the areas they are implemented the most are discussed. The areas to be focused on in the future studies to obtain more robust results in the optimization are identified.

Keywords— multi-objective optimization, Pareto optimal set, genetic algorithm methods, particle swarm optimization

In this study, articles included in the literature in the last 15 years and referred more than other articles written in the same year are analysed in terms of subjects, methodologies and results for Multi-objective optimization. These concepts in the literature are handled under separate headings. Multi-objective optimization methods can be divided into two groups as classical and heuristic methods. In this study, we explain the methods mostly used or referred in the articles. Each article is analysed in terms of its methodology under the relevant heading. Other unexplained methods and new approaches related to multi-objective optimization are analysed under the same heading. Methods chosen in the articles are analysed along with the reasons in the conclusion part. Success criteria of the studies conducted in special areas are mentioned. Subjects are suggested for future studies to obtain more solid results from multi-objective optimization.

II. MULTI-OBJECTIVE OPTIMIZATION

The main difference between single objective problems and multi-objective problems is that; there is a single optimal solution or alternative optimal solutions in single objective problems while there is not any solution simultaneously delivering the best value for each objective in multi-objective problems. Since all objectives are important in these problems, looking for a solution only for one objective is wrong. Improvements in an objective cause deterioration in at least one of the other objectives due to conflicting objectives. Trade-off amounts are obtained among identified solutions depending on their function values because of conflicting objectives. Acceptable trade-off amounts depend on decision makers. In this case, there is generally not a certain optimal solution in multi-objective problems. Some of the solutions obtained and traded-off are presented to the decision maker as the best solutions.

A general multi-objective optimization problem includes n parameters (decision variable), k objective functions and a group of m constraints. Objective functions and constraints are written as the function of decision variables. Optimization process can be formulated as

\[
\min \ y = f(x) = (f_1(x), f_2(x), ..., f_k(x)) \\
e(x) = (e_1(x), e_2(x), ..., e_m(x)) \leq 0
\]
\[ x = (x_1, x_2, ..., x_n) \in X \]  
\[ y = (y_1, y_2, ..., y_k) \in Y \]

Here it is appropriate to describe \( y \) as the decision vector, \( y \) as the objective vector, \( X \) as the decision space and \( Y \) as the objective space. Constraints \( c(x) \leq 0 \) show accessible solution set for the described problem. [1].

### A. Concept of Domination

Let a, b \( \in \) X be two separate solution vectors of a multi-objective optimization. In a problem with maximization type objective functions, solution a dominates solution b if \( f_j(a) > f_j(b) \) \( j \in (1, 2, ... n) \) is the case for each \( i f_i(a) \geq f_i(b) \) \( i \in (1, 2, ... n) \) and at least one \( j \). In the cases without dominance, a and b solutions cannot dominate each other for at least one \( i f_i(a) < f_i(b) \) and at least one \( j f_j(a) > f_j(b) \).[2]

### B. Pareto Optimality

A solution can be the best, the worst or equal to other solutions depending on its objective values. The best solution means a solution which is not the worst solution in any objective and is better than the other solutions in at least one objective. Pareto-Optimal solution is the solution not dominated by another solution in the search space [2].

Considering all objective functions, the set of all dominant solutions is called Pareto Front. The real aim of multi-objective optimization is to find or approximate to the Pareto front and enable a fair distribution over this front.

### III. CLASSICAL METHODS FOR MULTI-OBJECTIVE PROBLEMS

These methods are effective if the structure of multi-objective decision making problem aimed to be solved is appropriate and finding the best solution is possible if available. Regarding the studies using classical optimization techniques in general, Diakaki et al [38] evaluated the success of classical optimization methods in energy efficiency of buildings. They analysed the suitability of multi-objective optimization techniques in the solution of problems related to energy efficiency of buildings. They observed in the practices of a simple example. Ren et al [48] designed a modelling for the distributed energy resource (DER) using multi-objective linear programming (MOLP). This modelling was implemented within the scope of a case study in a eco-campus in Japan. Giarola et al [53] realized bio-refineries spatial design with Mixed Integer Linear Programming framework. In this way, they succeeded in simultaneously optimizing economic and environmental performances. Asadi et al [56] presented a multi-objective optimization model with Thebycheff formulation in order to reduce energy cost of buildings. They applied the model on a house by conducting required renovations and showed the feasibility of these approaches. Karande and Chakraborty [60] introduced a new approach for material selection problems in product designs. They developed a multi-objective optimization on the basis of ratio analysis (MOORA) independent from weights of selection criteria and normalization procedures of decision matrices. Najafi et al [63] suggested a source optimization model using classical optimization methods in order to provide the best immediate aid possible in post-earthquake response. Ehrgot et al [79] presented Minmax Robustness approach to obtain more robust results in classical optimization methods. They tried their approach on many linear and quadratic programming. Nariman-Zadeh et al [45] suggested a new multi-objective uniform-diversity genetic algorithm (MUGA) procedure based on developed \( \epsilon \)-elimination for vehicle vibration systems.

### A. Weighted-Sum

In this method, objectives are given weights, these weights are added together and a single weighted objective function is obtained. Weights are determined according to the importance attached to the objective by the decision maker. Optimal result can be obtained using the function composed of weighted objectives. Determining the weights can be difficult due to the lack of information on the problem during implementation of the method. If the problem is convex and the weights are positive, Pareto optimal solution is obtained [4]. In the other cases, in other words; if the problem is concave and the weights are not positive, it is wrong to look for a solution using this method.

Considering the studies using weight-sum; Altiparmak et al [29] developed the weight-sum approach in the design of supply chains network and a procedure finding Pareto optimal solutions. An experimental study using actual data from a company, which is a producer of plastic products in Turkey, was carried out. Xiang et al [44] came up with the multi-objective optimization (MOO) formulation for human lifting simulation with weighted-sum approach. They observed that the results are more sensitive compared to single objective optimization. Marler and Arora [46] investigated the impacts of weight selection in the solution stages of weighted-sum method and tried to solve the problem without knowing the weights in advance. Devarajan et al [61] presented an optimization modelling using weighted-sum in order to reduce the cost of wireless communication. They observed the results of the approach on simulation. Gjorgiev and Cepin [62] suggested an optimization approach using weighted-sum method for the combined economic-environmental power dispatch problem. They tried the algorithm in different power systems and they compared the results with multi-objective differential evolution (MODE) and NSGA-II. Sun et al [83] presented optimization modellings for patient and resource allocation among hospitals during a pandemic influenza outbreak. Weighted-sum was used in mathematical modellings.

### IV. MULTI-OBJECTIVE DECISION MAKING PROBLEMS BEYOND CLASSICAL METHODS AND GENETIC ALGORITHM

For the majority of multi-objective decision-making problems, it is almost impossible to obtain Pareto optimal solution set with classical methods. The reason is that most of the multi-objective problems are NP-hard [6].

Problems with integers are generally quite complicated and have a concave search space and it its hard to find the best solution set. Convergence to Pareto optimal solutions is quite
slow in classical methods. Searching for the optimal solutions for these is only possible with heuristic methods [7].

Genetic algorithm (GA) is the application of genetic related mechanisms in optimization problems as an algorithm. Reproduction in genetic generally occurs through mutation and crossover. These are GA operators. The obtained individual (solution) should have a good fitness value to maintain its participation. In this way, strong individuals succeed in survival and can transfer their genes to the next generations. Therefore, better solutions can be achieved by transferring the information on the solutions with good results to the next solutions [8].

To be able to use GA in a computer, the most compatible coding method for the problems should be used. The mostly used methods are binary coding, permutation coding and real number coding.

Selection of the solutions to be used in the next generation is one of the important steps in GA operation. Various selection methods were suggested as a result of research studies. Selection methods commonly used in practice include roulette wheel [9], selection sort [10] and tournament selection [11]. The common feature of these methods is that solutions obtained are probabilistically selected according to their compatibility value. Probability of the solutions with good compatibility value to be included in the next generation is always high.

Crossover and mutation are used to obtain new solutions using the selected solutions. Crossover is more commonly used compared to mutation operator. There are one-point, two-point and multi-point crossover techniques. It is observed that one-point and two-point crossover techniques are used the most. Mutation is an operator applied on solutions obtained after crossover operation. It is applied on the solutions with a small mutation probability identified beforehand and various solutions are obtained in this operation. Mutation operator provides diversity in the formation of next generations. It is possible to obtain bad results as well as good ones with crossover and mutation; however, these solutions are eliminated during selection. In GA, population extent should also be determined in addition to crossover and mutation control parameters. Most of the problems are quite sensitive to these three sensitive and the best solution is obtained only with the right selection of parameters [6].

Considering the studies using GA, Rao and Patel [66] presented a new approach for heat exchangers optimization using modified teaching-learning-based optimization algorithm. They compared the results obtained with GA results. Omkar et al [50] compared the results of the system designed for Vector Evaluated Artificial Bee Colony (VEABC) and its multi-objective optimization with PSO, Artificial Immune System (AIS) and GA.

V. MULTI-OBJECTIVE GENETIC ALGORITHMS

There may not be a single best solution for all objectives in multi-objective cases. In this case, the decision maker is asked to select a solution from a compromised finite set. Appropriate solution should perform at an acceptable level for all objectives. It is know that using genetic and evolutionary algorithms for the solution of multi-objective optimization problems is advantageous.

A. Multi-Objective Genetic Algorithm

Multi-objective Genetic Algorithm (MOGA) was developed by Fonseca and Fleming [13]. Groups are formed starting with the non-dominated solutions in the first group and solutions dominated for once in the second group. In each group, only the proximity of solutions to each other in the same group is calculated. Following the calculation of proximities, fitness parameter \( \sigma_{share} \) which should be a small number depending on the problem is identified. It is easy to calculate fitness values of the solutions in MOGA method. Furthermore, MOGA can be applied in various optimization problems with fitness parameter \( \sigma_{share} \). However, in this technique, giving the same fitness value to different solutions on the same front may cause the algorithm to look for the solutions on the wrong front. In practice, it has been proved that MOGA is quite sensitive to the type of concerned solution area. Besides, the algorithm does not guarantee that a solution has always a better fitness value than a worse solution [14].

Considering the studies using MOGA, Wang et al [25] optimized the conflicting economic and environmental objectives in environment friendly building designs with MOGA. They presented a case study and demonstrated the effectiveness of their approach for identifying a number of Pareto optimal solutions for green building design. Tahara et al [30] optimized various objective values in ship design with Sequential quadratic programming (SQP) and MOGA. They formulated a multi–objective optimization problem where ship propulsion and maneuverability performances are considered. Pierobon et al [72] realized Rankine cycles optimization for waste heat recovery using MOGA. They observed in the results that they could prevent heat loss.

B. Non-dominated Sorting Genetic Algorithm

Non-dominated Sorting Genetic Algorithm (NSGA) was developed by Srisvas and Deb [15]. The method starts with sorting the solutions obtained randomly according to their dominance. As in MOGA method, proximity among the solutions in each sub-population is calculated. Solutions are selected with roulette wheel method. In this method, the chance of the solutions in the non-dominated 1st sub-population \( P_i \) to be selected is higher. New solutions are obtained by applying crossover and mutation on the selected solutions and the algorithm keeps looking for solutions until stopping criterion is formed. NSGA method classifies solutions according to their dominance and assigns fitness values. Various practices have shown that the algorithm is especially \( \sigma_{share} \) sensitive to its parameter [15].

Considering the studies using NSGA, Ahmadi et al [70] aimed to obtain maximized power, thermal efficiency and minimized pressure loss using NSGA in Stirling heat engine design. They observed the results using experimental data.
C. Elitist Non-dominated Sorting Genetic Algorithm

Elitist Non-dominated Sorting Genetic Algorithm (NSGA II) was developed by Deb and Goel [18],[19]. This algorithm is similar to NSGA method; however, parameters used in NSGA are not used in NSGA II. NSGA II $\delta_{share}$ does not need the fitness parameter. The algorithm gives more chance to the prominent results and it is almost impossible to lose these solutions. Therefore, the algorithm never loses the Pareto optimal solution found until the current step. Solution selection mechanism is used to limit the population size; however, in this case, the algorithm may lose its feature of proximity to the optimal solution. Since the number of solutions in the sub-set $P_1$ where first non-dominated solutions exist is not higher than the number of main population, all solutions in this set are selected. Therefore, diversity among the selected solutions is not ensured.

In the studies using NSGA-II, Sarkar and Modak [23] developed a solution method for fed-batch bioreactors with NSGA-II. They applied this method on two problems included in the literature and solved with many methods previously. Atashkari et al [26] found out Pareto fronts of conflicting objective functions in the thermodynamic cycle of turbojet engines using $\epsilon$-elimination and NSGA II. Further, they observed some interesting and important relationships among optimal objective functions and decision variables involved in the thermodynamic cycle of turbojet engines. Deb et al [31] developed a new robustness procedure in order to obtain more realistic results instead of a general pareto front. They used NSGA II to compare global and robust pareto fronts. They managed many limited and unlimited test problems to show the obtained results through simulation. Goel et al [32] realized approximations on the Pareto Front obtained with NSGA II. They showed that the approximated Pareto optimal front (POF) can help visualize balances and quantify values among objectives to select compromise designs. Mandal et al [34] obtained Pareto set by modelling electrical discharge machining (EDM) with NSGA II. They carried out experiments over a wide range of machining conditions for training and verification of the model. Testing results demonstrated that the model is suitable for predicting the response parameters. Jia et al [40] worked on the optimization of energy, cost and scope parameters in the use of wireless network with NSGA II. Numerical and simulation results validate that the procedure to find the optimal balance point among the maximum coverage rate, the least energy consumption, as well as the minimum number of active nodes is fast and effective. Shokri et al [67] suggested a new method by combining NSGA-II and artificial neural networks (ANN) in order to reduce time spent for the solution of multi-objective optimization problems with evolutionary algorithms (EAs). The suggested method was applied on three standard problems and one real-life problem. They were able to considerably reduce the time required to find Pareto optimal front compared to NSGA-II solutions used without ANN. Campomanes-Alvarez et al [74] realized surface simplification optimization for a 3D open model mesh simplification problem. They compared the results obtained from NSGA-II and MOEA/D with the results obtained from two classical methods. Ahmad et al [78] presented a new approach by using NSGA-II in order to optimize each stage of biomass energy. They showed the Pareto front and observed the results with statistical analyses. Song et al [80] suggested a semi-active battery/supercapacitor (SC) hybrid energy storage system (HESS) for electric vehicles. They realized parameter optimization using NSGA-II in their studies.

D. Strength Pareto Evolutionary Algorithm

Strength Pareto Evolutionary Algorithm (SPEA) was developed by Zitzler and Thiele [20]. In this algorithm, diversity in the selection of Pareto optimal solutions is ensured with clustering analysis. Calculation of proximities is easy and additional parameters are not required. In the algorithm, parameter $N_L$, which is the size of populations where prominent solutions will be tracked, should be identified. Furthermore, balance between the main population size $N_{main}$ and $N_L$ should be ensured in order to obtain good results from the algorithm. $N_L$ should be neither too big nor too small. If it is too big, the algorithm loses much time with prominent solutions and may not generate other solutions and converge to optimal solutions. If it is too small, solutions in the prominent set are not used enough and it may cause the algorithm to excessively look for the solutions outside the area where optimal solutions exist. A criticised feature of the algorithm is that it gives a fitness value for dominance criterion to the solutions in the main population during the formation of populations. Furthermore, the power values obtained sometimes cannot keep the non-dominated solutions of the same importance at the same value [2].

Considering the studies using SPEA, Farmani et al [24] focused on certain objectives such as capital, operation, life cycle, maintenance costs, system reliability and water quality which should be simultaneously optimized in the design of water systems. Two examples related to design of water systems were applied on each of MOGA, NSGA and SPEA algorithms and their Pareto fronts were compared. Ali et al [57] amended Differential Evolution (DE) algorithm and transformed it into Multi-Objective Differential Evolution Algorithm (MODEA). They introduced new approaches to mutation and selection mechanisms in the meanwhile. The new approach obtained was applied on different multi-objective problems and the results were compared with algorithms NSGA-II, SPEA and Pareto Archived Evolutionary Strategy (PAES) developed by Knowles and Corne [21].

E. Strength Pareto Evolutionary Algorithm 2

Strength Pareto Evolutionary Algorithm 2 (SPEA2) was developed by Zitzler et al. [22]. It is the developed version of SPEA method. SPEA2 introduces a better scoring mechanism, an intensity estimation technique and a developed archive (secondary community) management compared to SPEA method. SPEA2 uses fine-grained fitness assignment strategy using intensity information. Furthermore, size of the archive externally storing the non-dominated individuals is stable. If
the number of non-dominated individuals is lower than the previously identified archive size, the archive is filled with non-dominated individuals. Additionally, the clustering technique used when non-dominated surface is over the archive size was replaced with an alternative downsizing method that has similar features but does not lose front points. Finally, another difference from SPEA is that only the archive members are used in selection process.

Considering the studies using PSO; Wang and Singh [35] designed a developed optimization practice with NSGA-II and SPEA2. In this way, they realized meta-heuristic and experimental practices in the solution of multi-objective optimization applications. Xue et al [75] realized a feature selection optimization using PSO with the aim of reducing surplus and unnecessary features in the data sets and obtain more accurate results in a shorter time in classification. They compared the results obtained with NSGA-II, SPEA-II and PAES.

VI. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization is a swarm-based algorithm developed by Kennedy and Eberhart in 1995 with the inspiration from fish schools and bird flocks in the nature [12]. The algorithm was built on the behaviours of flock animals practices in order to meet essential needs. Particle concept used in PSO algorithm represents each individual in the swarm. Each individual in the swarm has position information indicating the position of the individual in d-size solution space and speed information indicating its movement in d-size solution space. PSO is a repetitive algorithm. Therefore, speed and position information of the particle is updated during each repetition. While speed information of the particle is updated, not only the heuristic speed information from the previous step but also cognitive and social experiences are used. For the updated position information of the particle, position information and updated speed information of the particle from the previous step are used. [12, 16].

Considering the studies using PSO; Wang and Singh [35] suggested fuzzified multi-objective particle swarm optimization (FMOPSO) for the compromising economic and environmental objectives in electricity transmission. The performance of the suggested approach was compared with Weighted Clustering (WA) and evolutionary multi-objective optimization algorithms. Tripathi et al [36] developed Time Variant Multi-Objective Particle Swarm Optimization (TV-MOPSO) procedure based on PSO multi objective optimization approaches and measured the performance by comparing with algorithms such as NSGA II and PESA II. Zhang and Liu [39] presented a new formulation with fuzzy adaptive PSO (FAPSO) for multi-objective reactive power and voltage control. The proposed approach has been examined and tested with promising numerical results of the IEEE 30-bus and IEEE 118-bus power systems. Zhang and Xing [47] developed a construction method with PSO for the time–cost–quality trade-off problem. They applied the suggested method with computerized analyses and verified. Moslehi and Mahnam [49] presented a new approach for flexible job-shop scheduling problem using particle swarm optimization and local search. They compared the efficiency of the approach presented with other algorithms in the literature. Qasem and Shamsuddin [51] applied TV-MOPSO on radial basis function (RBF) used in the diagnosis of medical disorders. They compared the results with MOPSO and NSGA II. Yildiz and Solanki [59] presented a new method for the multi-objective optimization of crashworthiness of vehicles. The PSO-based method was applied on two optimization problems in the literature. Khalili-Damghani et al [64] suggested dynamic self-adaptive multi-objective particles warm optimization (DSAMOPSO) for the solution of multi-objective reliability redundancy allocation problems (MORAPs). They compared the results obtained from test problems with TV-MOPSO and NSGA-II results. Garg and Sharma [65] reformulated multi-objective reliability-redundancy allocation problem with fuzzy multi-objective optimization problem (FMOOP). They solved the fuzzy MOOP obtained using PSO. The approach has been demonstrated through the case study of a pharmaceutical plant situated in the northern part of India. Zhang et al [68] realized an uncertain orbit optimization using risk and orbit distance parameters in the problems related to orbit planning for robots. In their studies, they used PSO and observed the results from simulation. Taormina and Chau [82] created a multi-objective problem using cross-validation for PSO-trained neural network river forecasting (NNRF). They solved this problem with multi objective fully informed particle swarm (MOFIPS) approach using actual data.

VII. OTHER METHODS AND NEW APPROACHES

New approaches presented for the solution of MOOPs and methods developed for special systems are handled. Mahapatra and Roy [27] developed a new fuzzy multi-objective optimization method in order to increase system reliability. The main aim was to increase reliability while reducing the cost. Huang et al [28] developed a special interactive fuzzy multi-objective optimization model for engineering designs. In this model, balance matrix was used and weight coefficients of objective functions were identified depending on preference. Igel et al [33] transformed covariance matrix adaptation evolution strategy (CMA-ES) delivering quite good results in single-objective optimization for multi-objective (MO-CMA-ES) and elitists problems. Obtained results were compared with NSGA II. Jaeggi et al [37] adapted Tabu Search algorithm for the solution of MOOPs. All results were compared with MOTS (Multi-Objective Tabu Search), PRMOTS (Path Relinking Multi-Objective Tabu Search) and NSGA II. Thiele et al [41] elaborated the obtained pareto optimal set with the instantaneous preferences of the user in each repetition using multi-objective evolutionary algorithm (MOEA). In this way, they managed to include ignored but essential solutions in the pareto optimal set. Kim et al [42] designed multi-objective population-based incremental learning (MOPBL) for the fuzzy path planning of robots. Simulation and experiment results show the effectiveness of the proposed MOPBL from
the viewpoint of the proximity to the Pareto-optimal set, size of the dominated space, coverage of two sets and diversity metric. Chaudhuri and Deb [43] developed a procedure to assist users to select a specific solution on the obtained pareto optimal set with multi-objective evolutionary optimization (EMO). Huang et al [52] developed a new online multi-objective optimization algorithm for membrane computing. They prevented the formation of undesired and wrong solutions with online controls in this dynamic algorithm. Yang [55] developed the multi-objective bat algorithm (MOBA). He applied the algorithm on the problems related to welded beam design and observed its success in the results of simulation. Fesanghary et al [58] presented a model based on harmony search algorithm (HS) in order to minimize life cycle cost (LCC) and carbon dioxide equivalent (CO2-eq) and maximize energy efficiency of the buildings. To measure the efficiency of the proposed approach, they tested the performance of the model on a typical single-family house. Jiménez et al [69] conducted an optimization study on production planning using fuzzy multi-objective evolutionary algorithm. They compared the results with NSGA II. Sindhya et al [71] attempted to eliminate the problems arising in optimization process with multi-objective evolutionary algorithms (MOEA) using new hybrid systems. NSGA-II and MOEA types were transformed into hybrid systems and the results were compared. Niu et al [73] developed a new multi-objective Bacterial Foraging Optimization (MBFO) algorithm and compared the obtained results with NSGA-II and MOPSO. Wang et al [76] presented an approach for cost-energy optimization in the coal-fired thermal power plants. In their approach, they used multi-objective differential evolution (MODE) and showed the results with simulation. Huang [77] developed a design optimization for design exploration of three-dimensional transverse jet in a supersonic crossflow and observed the results with simulation. Wang et al [81] presented a multi-objective optimization for combined cooling, heating and power system (CCHP). In the experiments conducted, it was found out that a more comprehensive solution set is required to obtain more successful results from optimization.

VIII. CONCLUSIONS

In this study, 61 articles published in the last 15 years are selected and analysed. Each article is handled under separate headings in terms of their subjects, methodology and results. As a result of the analysis, it is observed that operations using multi-objective optimization techniques are quite successful in the solution of comprehensive problems which is a huge challenge for operators in the special areas. The method used in the solution of MOOPs should be chosen considering the objectives and constraints peculiar to each area. Because classical and heuristic methods do not deliver the same results in the same operation. While determining the classical and heuristic methods to be used in article analyses, the extent of information available on the handled problem is quite effective. If the importance of each objective and constraint is known in numbers for the problem aimed to be solved, mostly classical methods are preferred. To be more precise, the more the problem is complicated and unknown, the more the probability of selecting heuristic methods increases. Classical methods are chosen when complete and certain results are desired to be obtained. In the operations where solution performance is low due to the complexity of the problem, pareto optimal set which can satisfy the operator and show the approximate results is obtained. In the articles, finding the algorithms that can present the pareto optimal set most accurately and in the shortest notice becomes prominent as the main aim.

Another outstanding subject in the articles is NSGA-II which is one of the multi-objective genetic algorithm types among heuristic methods. It was observed this algorithm delivers the most diversity in the solution of problems. This algorithm either serves as the main method of many operations or the developers use a variant of this algorithm. The abundance of NSGA-II use in the measurement of special algorithms developed is outstanding. In the studies using PSO, the most remarkable feature of PSO is its easy practice in most of the systems. Developers have experimented many variants of PSO on the same problem and compared the results.

Considering the studies in the special areas, it is observed that multi-objective optimization methods in the literature are either used in the same way or their variants are applied. The success of algorithms developed in the studies are measured with the comparison of results from many methods applied on the same problem.

One of the biggest problems arisen during the studies is the ignorance of essential solutions for users while finding the pareto optimal front. All these observations bring this question to the mind: Is it possible to develop a multi-objective optimization method that can be applied on optimization problems in each area and provide the maximum performance in the solution? For the answer of this question, it is observed that studies on the performance of multi-objective optimization among the articles are quite important. The outstanding point in these studies is the interaction between application and user. If the future studies focus on increasing the performance and robustness of multi-objective optimization, methods delivering results where most approximate values to the solution are found in the shortest notice and essential solutions for the operators are not ignored can be developed.

REFERENCES


Long Range Wireless Point to Point Link Network on 5 GHz Frequency Band with VoIP

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Abstract— 802.11 Wi-Fi technology is commonly used for creating wireless access networks with a maximum range of one hundred meters. With careful planning and proper antennas, this same technology can also be used to make point to point links up to several kilometres. Since, it is not always feasible and wise to run cables over long distances to connect different networks, therefore, wireless links may turn out to be cost effective alternative to their counterpart wired links while creating long distance networks and providing network scalability. Wi-Fi-based point to point links can therefore be used to connect two local area network (LAN) segments, which besides being cost-effective, provides network scalability and other advantages such as high speed, centralized and easier management and high throughput for line of sight (LOS) applications. A Wi-Fi-based point to point link can extend the range of wireless LAN by a few hundred feet to few miles which can further be increased by using highly directional antennas for point to point links, while serving as a backup network in different organizations. So, we have designed a soft private branch exchange (PBX) system for a university campus or organization, facilitating voice over internet protocol (VoIP) calls and instant messaging, employing the idea of Wi-Fi based point to point links. Moreover, we have also analysed the quality of service (QoS) of the given setup in terms of data rate and connectivity using bandwidth test and ping test respectively, for both transmission control protocol (TCP) and user datagram protocol (UDP) scenarios.

Keywords— Wireless Point to Point Bridge Link, LAN segments, Soft PBX, VoIP, Instant Messaging, QoS.

1. INTRODUCTION

Many rural regions in developing and developed countries with low user densities do not have good connectivity solutions with a low budget. In low density environments, people are usually clustered around small localities, with large distances among these clusters. The example of such environments is a large enterprise situated in premises, with different departments or buildings at a distance or possibly villages or sub-urban areas. In such cases, traditional options to provide connectivity are not economically viable [1].

Fibre optics can be a very good choice for long distance backbone networks. It provides good reliability but it is not suitable for network scalability. Besides its installation and maintenance costs are quite high. So in case of low density environments and intranet connectivity, they turn out to be expensive and resources are wasted as well. Satellites technologies are very efficient for broadcast traffic, but when it comes to bidirectional internet and intranet access and interactive communications, they tend to be severely limited in throughput and costly. Traditional microwave links can scale in throughput but generally require licensing and hence are expensive to be utilized. Networks with base station model such as Worldwide Interoperability for Microwave Access (WiMAX) and cellular networks like General Packet Radio Service (GPRS) and Code Division Multiple Access (CDMA) consist of expensive base stations, which do not cover enough users in low-density regions and hence lead to the waste of resources [2].

Wireless mesh networks are generally established using the 802.11 Wi-Fi technology and serve to provide internet access in high user density environments. These wireless mesh networks provide full coverage of the region using Omni-directional Access Points (APs) over a range of about one hundred meters. But mesh networks suffer from two major short comings when scaled to larger areas. First, an increase in number of APs in the growing network with Omni-directional antennas leads to increased interference in over-lapping cells. Second, the use of low gain Omni-directional antennas increases the hop length, resulting in a decrease in throughput [2]. Thus, it can be implied that for low density of users, traditional approaches that provide full coverage or require wiring of sites are not feasible. The alternative is to cover only those few places where connectivity is required, by employing long distance wireless point to point links. Such links can be employed using Wi-Fi for low cost and ease of configurability. Hence, the best solution for internet access and intranet communications in low density environments and some organizations is using Wi-Fi in bridge mode providing point to point and point to multipoint links [1].

Wi-Fi-based point to point links have proved to be the cost effective alternative to their counterpart wired networks to provide communication over long distances, especially in rural areas and within an enterprise or premises. Wi-Fi-based point to point links are relatively cheap and provide a number of advantages such as network scalability, high speed, centralized and easier management and high throughput for Line of sight (LOS) applications. Wi-Fi-based point to point links can extend the range of wireless local area network
(WLAN) by a few hundred feet to a few miles, by segmenting it, using highly directional antenna and adequate planning for these point to point links. They can also serve as a backup network in different organizations.

Therefore, in this paper, we propose the idea of Wi-Fi-based point to point links for any type of low density environment with voice over internet protocol (VoIP) and instant messaging services in a soft private branch exchange (PBX) system. We setup a server to enable these applications at one end of the soft PBX system and configure the APs to enable Wi-Fi-based point to point links for providing services at the other end of the soft PBX system. Furthermore, we also analyse the quality of service (QOS) of the given setup in terms of data rate and connectivity using bandwidth test and ping test respectively, for both transmission control protocol (TCP) and user datagram protocol (UDP) scenarios.

The rest of the paper is organized as follows. In Section II, related terminology used in this paper is discussed and Section III puts light on the system model. Section IV explains the soft PBX system and Section V presents observations. Section VI finally concludes the paper.

II. RELATED TERMINOLOGY

A. Wireless Bridges

We use wireless bridges in our system to connect network segments using point to point links. LAN would be flooded with unnecessary traffic if the messages are broadcasted to every destination in that network thus bridges are usually used for the segmentation of LAN and interconnection of LAN segments. A bridge network solution does not necessitate difficult configurations, like IP routing. The bridge network manages LAN segments and creates a single subnet for the entire network. Bridges work at the data link layer of the Open System Interconnection (OSI) model. Bridges learn which addresses are on which network segment and develop a forwarding table so that subsequent messages can be forwarded to the right network segment. Bridges examine the incoming packets and look up the forwarding table for their destination media access control (MAC) address. If the destination MAC address is found in the forwarding table, the packet is forwarded to the corresponding port and if the destination MAC address is not found in the same segment, the bridge restricts the transmission [3].

Wireless bridges are same in functionality and used to connect two LAN segments via a wireless interface such as a radio link, to facilitate connectivity and data transfer between them. Wireless bridges are commonly used to interconnect wired network segments such as an Ethernet network via wireless link. In simple terms a wireless bridge is a device that allows two network segments of users to transparently communicate to one another over long distances without wires. They can be used to connect areas that are geographically apart like a remote building to the main building up to 30 miles, using proper antennas and LOS. Connecting two locations wirelessly through a wireless bridge is much more cost effective than the installation and maintenance of a wired network whether it is fiber optics or copper, for the same purpose. Wireless bridges provide connectivity when it is difficult to wire the sites. Moreover, with wireless bridges, network scalability can be performed very easily by just providing another AP working in the bridge mode at the place of interest [4].

B. Wireless APs

Wireless access points (APs or WAPs) are specially configured nodes on WLANs. These are the network devices used to connect multiple wireless devices to wired LAN, for accessing internet. APs act as a central transmitter and receiver of WLAN radio signals. APs used in home or small business networks are generally small, dedicated hardware devices featuring a built-in network adapter, antenna, and radio transmitter. APs support 802.11 wireless communication standards. Usually, WAPs operate in "root mode", a point to multipoint configuration in which the AP relays frames between many 802.11 stations and an adjacent Ethernet LAN. However, WAPs also have bridging mode that can be configured for connecting LAN segments in point to point link configuration. Wireless bridges relay frames between LAN segments using the same 802.11 wireless communication standards [4].

C. 2.1 FCC Rules for 802.11 Standards

Since, Wi-Fi 802.11 standard operates in an unlicensed Industrial scientific and medical (ISM) band therefore, the signals operating over that band can interfere with each other. So, there are some rules defined by FCC to cope up with it that put some limitations on the power or Effective Isotropic Radiated Power (EIRP) of the signals radiated on this band. These rules are different for 2.4 GHz and 5 GHz operating frequencies of ISM bands as well as for point to point and point to multipoint topologies. In this project, a point to point link is established between LAN segments operating on the 5 GHz band within the limitations defined by FCC, which state that, "For maximum transmitted power of 30dBm, a directional antenna gain of 23dBi can be used with no reduction of transmitter power output in point to point links. However, if directional antenna gain increases greater than 23dBi, a 1dB reduction in peak transmitter power is required for each 1dB increase in antenna gain greater than 23dBi" [5].

D. Fresnel Zone Clearance in Point to Point Links

We use 5 GHz ISM band to establish point to point link in our system that falls in the microwave region of electromagnetic spectrum. Microwave links are generally used for LOS communications as microwaves are highly directional and travel in straight lines. But the energy of microwaves is not pencil thin. They spread out the farther they get from the antenna. The area that the signal spreads out is called Fresnel Zone. If there is an obstacle in the Fresnel zone, part of the radio signal will bent away from
the straight line path which will result in the reduction of the amount of radio frequency (RF) energy reaching the receiving antenna. Fresnel zones can also be viewed as the concentric ellipsoids surrounding the transmitter, receiver and the LOS between them. The first Fresnel zone is the region where the microwave transmission energy is the most intense and it is the closest to the direct line between transmitter and receiver, as shown in Fig. 1.

![Fig. 1 Fresnel Zones](image)

The obstruction in the first Fresnel zone can even lead to link failures. Therefore, the Fresnel zone clearance is the most crucial phenomenon while designing the microwave point to point link. In order to provide a lossless communication via point to point microwave link, the radius of the first Fresnel zone should be 60 per cent clear of any obstruction. This Fresnel zone clearance can be achieved by adjusting the antenna heights at both the transmission and reception ends [6].

E. Devices for Point to Point Link

We use MikroTik SXT 5HnD devices to connect LAN segments with a point to point bridge link. These are low cost, versatile and high speed devices, operating at 5 GHz frequency of ISM band. The devices include many important features such as support for 802.11a/n wireless standard, transmitter power of 26dBm, built-in 16dBi dual chain antenna, 10/100 Ethernet port and others. These devices have their own proprietary wireless protocol, named as Nv2 for use with 802.11 wireless chips. Nv2 protocol is specifically based on Time Division Multiple Access (TDMA) technology for long range point to point links instead of Carrier Sense Multiple Access (CSMA) technology for 802.11 devices. Nv2 protocol in AP enables to control media access by dividing time in fixed size slots. These slots are dynamically allocated in downlink (data sent from AP to clients) and uplink (data sent from clients to AP) portions, based on queue state on AP and clients. Nv2 is different from 802.11 as the media access is scheduled by AP. AP controls that how much time is used by every client and time is assigned to clients according to some policy not according to contention based methods like in 802.11 standards. Also propagation delay is reduced in Nv2 as there are no per frame acknowledgements. Nv2 implements frame aggregation and fragmentation to maximize the assigned media usage and reduce per frame overhead. The devices also include high throughput (HT) to enable the use of MIMO feature of 802.11n standard used in the device. With HT chains 0 and 1 enabled at the transmitter and receiver sides, 2 by 2 antenna diversity and spatial multiplexing can be achieved which significantly increases the throughput of the device. With “HT guard interval” option, the length of guard interval can be adjusted to minimize the inter symbol interference while maintaining the desired throughput [9].

III. SYSTEM MODEL

The point to point microwave bridge link is established to connect the LAN segments in the two buildings that are 1km apart in the campus. For proper transmissions the two antennas should be properly aligned and should have a clear LOS with 60 percent of the Fresnel zone unobstructed. From the site survey, it was observed that there are obstructions between the two departments so the antennas are needed to be mounted at a considerable height to get an unhindered path. The system model in Fig. 2 shows how different devices are connected to establish the point to point link between LAN segments and provide intranet connectivity as well as internet access. The AP at one side of the link is configured as the bridge or AP while on the other side, it acts as the client. The client is connected to a switch/router to which wired device (such as PCs) as well as wireless devices (like laptops, phones) can connect and use the wireless link. The AP at the other end is also connected to a switch/router to which the IP PBX server is attached for VoIP communication and instant messaging. Other wired or wireless devices can also connect to it for intranet communication. The switches/routers transfer the VoIP calls/instant messages within a LAN segment and the APs (configured in AP or bridge mode) transfer the VoIP calls/instant messages to the other LAN segment. Ethernet cables and Power over Ethernet (POE) adapter are used for interface and power.

![Fig. 2 System Model for Wireless Point to Point Bridge link](image)

A. Configuration of Devices

We use two RouterBoard SXT G-5HnD access points to establish the link. One of them is configured as a bridge (AP) and other as a station bridge (client). The devices are graphically configured using Winbox software/ application. After logging into the devices at both AP/client end, both MAC and IP addresses are configured first and then their identities are defined as AP or client.
Wireless point to point link is created at both AP and client by defining different interfaces with address resolution protocol (ARP) enabled. The wireless characteristics of the point to point link such as band, channel width, frequency and wireless protocol are set to be 5 GHz, 20 MHz, 5180 MHz and Nv2 respectively at both AP and client end of the LAN segment. The manual transmit power is set to 30dBm as per FCC rules requirement at the client end. All HT chains are enabled at both AP and client ends to provide MIMO feature and the guard interval is kept 800ns to avoid inter symbol interference and get a more stable link. After setting the wireless point to point link, it is necessary to make bridge configurations at both ends of the LAN segment. At both AP and client side, rapid spanning tree protocol (RSTP) is used to prevent bridging loops and two interfaces are defined, one for the point to point bridge link and the other for connecting to the particular LAN segment. We use Dynamic host configuration protocol (DHCP) to provide automatic IP address to the devices, connected to each LAN segment for soft PBX calls and instant messaging. The configuration is made on AP device that is connected to the soft PBX server. A static IP is defined for the gateway DHCP and the rest of the IP addresses are allocated dynamically from the DHCP pool for a maximum lease time of 3 days.

IV. SOFT PBX

PBX is a telephone switching system owned by a company that manages incoming and outgoing calls for the company’s internal users. Companies lease only one line and have many people using it, with each one having a phone at the desk with different number, called extension. PBX automatically sends incoming calls to the required extensions. A PBX hence can switch calls within the organization and can also connect to the Public switched Telephone Network (PSTN) for calling outside the organization. A conventional PBX can be costly as it requires copper wires and other hardware equipment. Soft PBX (also called IP or virtual PBX) is a telephone system used for the sending voice over the internet protocol (IP) network and is same in application as the conventional PBX but functions differently. It is based on a computer PBX software and voice over internet protocol (VoIP) instead of relying on the traditional telephone hardware and copper circuits. A soft PBX system uses a single network for data traffic and voice calls, both encapsulated in IP packets and then transferred over the network, unlike conventional PBX. The major part of the soft PBX is handled by the software so they are relatively inexpensive. A soft PBX system consists of three components; phones, soft PBX server and an optional VoIP gateway. Phones should capable of supporting VoIP. Soft PBX software installed in PC can serve the purpose of a soft PBX server. VoIP gateways are optional and are used to connect to the external land line PSTN. The users in soft PBX register their session initiation protocol (SIP) address, very much like extensions in conventional PBX, with the soft PBX server, which maintains a database of all its users and their corresponding SIP addresses. The VoIP telephone calls are established modified and terminated using the IP telephony protocol SIP. To make a call, the server is requested to establish a connection. When the called party’s number is dialed, the IP address of the phone is mapped to the corresponding SIP address and then it is sent to the destination. The calls to and from PSTN are routed via VoIP gateway. If the call is to be made outside the soft PBX network, the server directs it to the gateways from where it is sent towards the PSTN. Similarly the calls from PSTN are directed to the server via the gateway and the server then sends them to the appropriate destination [8].

A. For VoIP calls

For VoIP calls, we use Asterisk which is open source soft PBX software that can use both traditional Time Division multiplexing (TDM) technology and packet voice protocols (VoIP and Voice over Frame relay). Asterisk acts as a full featured PBX, supporting virtually all conventional call features on SIP phones like Caller ID, Call waiting, Call forward/busy, Call forward/no answer, Voice mail, Least cost routing, Call conferencing and many more. Asterisk supports three VoIP protocols, two industry standards and one specifically for Asterisk. Inter-Asterisk exchange (IAX) is the de-facto standard for Asterisk networking. The other protocol used by Asterisk is Session initiation Protocol (SIP) which is an Internet Engineering Task Force (IETF) standard for VoIP. The last one is H.323 which is an International Telecommunication Unit (ITU) standard for VoIP. Asterisk provides seamless and transparent translation among so many codecs and file formats such as A-law, u-law, GSM 6.10, MP3, PCM, VOX and LPC-10 [9]. In order to configure soft PBX, we download and install Asterisk10 along with its packages on Ubuntu Linux operating system. SIP file is edited to define SIP clients, codecs used, mailbox addresses and other options. We set different extensions for each SIP client or user under the context of phones and a shared password is used to authenticate each phone. The user reachability checks are performed every 60seconds. Out of all codes available, we use only u-law, A-law and GSM codes in our soft PBX system. Mailbox is used for the voice mail messages such that the voice mails for the user having extension 101 will be saved at 101@default. Dial plan file is created to handle incoming and outgoing calls such that the commands are executed in the following order: when there is a call for some extension, direct the call to that extension. After 20s the called party is asked to leave their message which will be saved at extension@phones. The server is then directed to play an audio file and then hang-up the call. A separate file for voicemail is made with a separate extension such that the called party is directed to the main voice mail system to check the voice mails if there are any.
All files are reloaded after their configuration.

B. For Instant Messaging

Open fire version 3.8.0 server is used in the project to facilitate instant messaging which uses the only widely adopted open protocol for instant messaging; that is Extensible Messaging and Presence Protocol (XMPP) (also called Jabber). Jabber is an open, Extensible Mark-up Language (XML)-based protocol for instant messaging written in Java. Open fire can support Instant Messaging Transports that provides connectivity to external Instant Messaging services such as Yahoo Instant Messaging, Microsoft Network (MSN)/Windows Live Messaging and Google talk Messaging. The server is also compatible with the Asterisk 10 server used for VoIP calls in the system. Concisely, open fire is a freeware open source server that provides instant messaging, broadcast messaging, offline messaging and group chat. Open fire also provides a higher degree of security to the end user as the clients are connected to the server using the Secured Sockets Layer (SSL) secured connection so; the traffic streams in both directions are encrypted. The server also provides a way of authentication to its clients for improved security using a different user ID and password for each client. Whenever a client is registered to the server, the user ID and password for that instant messaging service are stored in encrypted form on the server and are used for client authentication. Open fire is based on the protocol that runs on Java so open fire requires Java Run time Environment (JRE) and Java development Kit (JDK) to operate. Open fire also requires MySQL server to make its user accounts database [10]. Therefore, first the latest versions of Oracle JRE/JDK are installed on the Linux server and then MySQL database server and client packages are installed. When the MySQL server and client packages are installed, the database or user accounts are ready to be set. MySQL has its own user accounts which are not related to the user accounts on the Linux machine for VoIP calls. By default, the root account of MySQL server is empty so, root accounts along with the passwords are defined. A new MySQL database is created for Open fire with a new username and password. After that, Open fire 3.8.0 is downloaded, installed and configured. For the configuration of Open fire, first administrator account is setup with email and password and then the administrator account is used to create users/clients with their corresponding usernames, email addresses and passwords.

V. OBSERVATIONS

Once the point to point bridge link is established and it is working properly, it becomes important to analyze the QOS provided by the link for the VoIP calls and instant messaging services. The key parameters to estimate the QOS of any network are its delay, bandwidth or data rate and packet loss. These parameters are tested one by one over the link to observe the QOS by the link for each service.

A. Bandwidth Test

Bandwidth test is done to get the bandwidth and data rate of the link in both directions that is transmit and receive, at both AP and the client. Bandwidth test also gives the packet loss at an instant when some particular number of packets is sent. Bandwidth test is done in two different scenarios of TCP and UDP as they provide different results in terms of data rate and packet loss. Bandwidth test performed at the AP device gives the results shown in Fig. 3. Results are taken for UDP as well as TCP in both directions when the transmitted and received packet sizes are 1500 bits. The QOS analysis for UDP shows that the data rate at the transmission is 45 Mbps and at the reception is 54.5 Mbps giving the total data rate of about 99.5 Mbps in both directions that can adequately make several voice calls and data transmissions simultaneously. For a packet size of 1500 bits per packet, almost 66,333 packets are transmitted per second in both directions at a bidirectional data rate of 99.5 Mbps, out of which 554 packets are lost at an instant. Therefore, the packet loss is never exceeding 1 percent which is optimum for voice calls and data transmission. For TCP, it can be clearly seen that the packet loss is 0 since TCP is a connection oriented reliable protocol in which each transmitted packet is acknowledged and none of the packet is lost. However, due to multiple acknowledgements, the data rate is significantly reduced to 9.1 Mbps at the transmission side, 24.3 Mbps at the reception side and a total data rate of 39.4 Mbps in both directions. But the data rate is still enough to send multiple voice calls and data files simultaneously. Bandwidth test performed at the client device gives the results presented in Fig. 4. The results for UDP show that the data rate at the transmission side is 61.5 Mbps and at the reception is 32 Mbps, giving a total data rate of 93.5 Mbps in both directions that is optimum for making several voice calls at the same time and the packet loss is seen to be zero even for UDP protocol. The results for TCP protocol at the client side show that the effective data rate is reduced to 25.8 Mbps at the transmission side and 11.3 Mbps at the reception side summing up to a total data rate of 37.1 Mbps in both directions. The packet loss is zero for the same reason of reliability.

B. Ping Test

Ping is an acronym for the word “Packet internet gofer”. Ping works over Internet Control Message (ICMP) protocol that checks for the relative connectivity in the network. So, ping test is performed to check the connectivity of the link and an average delay that it takes for a packet to be sent to a destination and receive a packet in response from the destination. Ping test is performed at both the AP and client devices to check connectivity and delay at both ends. Ping test is performed at AP to check its connectivity with the client. Ping test performed at the AP device gives the results, as depicted in Fig. 5. As seen from the ping statistics of the packets sent and ping replies, it is clear that
the average delay is not exceeding above 7ms that is quite appropriate for making several voice calls and data transmissions simultaneously. The continuity in ping replies also assures the reliability of the link for making voice calls. Ping test at the client is performed to check its connectivity with the AP client and delay in packet transmission and reception. Ping test made at the client device gives the results, as shown in the Fig. 6. The results show that the minimum delay of the link for transmission and reception of packets is 3ms and average delay is 18ms. This delay is a little greater than the delay observed in the ping test performed at the AP device but still satisfies the QOS requirements for voice calls and instant messaging.

![Fig. 3. Bandwidth Test at AP for UDP and TCP](image3)

![Fig. 4. Bandwidth Test at client for UDP and TCP](image4)

VI. CONCLUSION

In this work, we have used wireless point to point bridge link to connect LAN segments located separated 1km apart and provide VoIP and instant messaging service using soft PBX in both LAN segments. Although wireless bridge link operating in an unlicensed band and can suffer from interference and lack of reliability, but these shortcomings can be adjusted with proper planning of the link. Wireless bridge link can offer outstanding advantages such as cost effectiveness, suitable data rate, easier installation, easier trouble shooting and scalability for low density environments.

REFERENCES


Abstract — Detecting the rail surface faults is one of the most important components of railway inspection process which should be performed periodically. Today, the railway inspection process is commonly performed using computer vision. Performing railway inspection based on image processing can lead to false-positive results. The fact that the oil and dust residues occurring on railway surfaces can be detected as an error by the image processing software can lead to loss of time and additional costs in the railway maintenance process.

In this study, a hardware and software architecture are presented to perform railway surface inspection using three-dimensional laser cameras. In addition two-dimensional data that Ccd/cmos cameras have on the x-y plane, laser cameras have three-dimensional input data as they include precise distance information on the z plane. Generally, three-dimensional data acquiring processing is very commonly used in machine vision applications such as mobile robots, image enhancement, medical and fault diagnosis. The use of three-dimensional laser cameras in railway inspection process provides high accuracy rates. The reading rate of laser cameras to read 10,000-30,000 profiles per second is another important advantage provided in real time railway inspection.

Consequently, a computer vision-based approach in which three-dimensional laser cameras that could allow for contactless and fast detection of the railway surface defects such as fracture, scouring and wear with high accuracy are used in the railway inspection process was proposed in the study.

Keywords — Railway Inspection, Anomaly Detect, Computer Vision, Laser Camera, Machine Learning

I. INTRODUCTION

In industrial applications, it is necessary to conduct activities such as maintenance, condition monitoring and fault detection as well as production and R & D activities. In recent years, these operations are commonly conducted using computer vision [1]. Computer vision ensures that these operations are conducted fast with high accuracy and without human dependence. Due to all these advantages offered by it, the maintenance, monitoring and fault detection conducted using computer vision are also commonly used in railway rail inspection as in other fields of the industry [2].

Rail transportation systems are widely used all around the world. The anomalies that could occur or are present on railway can lead to both troubles and financial losses and accidents in the transportation system. Therefore, the rail line should be checked periodically [3].

Today, the rail inspection operation is basically divided into two groups as contact and contactless methods. The simplest method of inspecting is that an expert visually inspects the rail line with mechanical measuring instruments. This method is limited by very slow, low accuracy specialized knowledge inspecting the rail line [4]. Another one of the contact methods is performing the rail inspection with ultrasonic devices. Fault detection is conducted by analyzing the data and graphics obtained by the friction of the mechanical device which is moved along the rail line to the railway rail line [4]. The inspection process is slow in this method shown in Fig. 1. Its most important disadvantage is that the mechanical device can increase the existing fault on the rail line or new faults may occur because of the device's necessity of friction to the rail line during inspection.

Although contact methods are low-cost, they have significant disadvantages because they do not have high accuracy ratios and the inspection process is long. Today, rail inspection operation can be performed rapidly as contactless and with high accuracy using computer vision. The general components of a computer vision-based rail inspection operation are seen in Fig. 2 [6].
The long rail inspections can be inspected real-timely in the contactless rail inspection operation that uses the computer vision. The inspection operation consists of the steps of determining the components of the rail line and the deficiency (such as missing traverse and bolt) or anomaly conditions in these components [7-13].

The rail inspection applications in which light source and high resolution cameras are used may lead to the generation of false positive results by detecting the stains formed by oil and dust particles on the rail line as anomaly in addition to high accuracy ratios and real-time operating speeds [8].

When three-dimensional laser cameras are compared with normal cameras, they involve both rgb data and precise distance information on the two-dimensional plane. Because of these features, they are widely used with the aim of finding faults in industrial products including rail inspection [9-12]. Although the cost ratio inspection with 3-d cameras is higher, it is the most advantageous method in terms of accuracy rate and operating speed. The rail inspection methods are comparatively presented with their specific advantages and disadvantages in Table I [4].

**TABLE I**

<table>
<thead>
<tr>
<th>Methods</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanic devices</td>
<td>Cheap</td>
<td>Very slow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unsafe</td>
</tr>
<tr>
<td>Ultrasonic devices</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase existing damage</td>
</tr>
<tr>
<td>Computer vision</td>
<td>Safe</td>
<td>Expensive</td>
</tr>
<tr>
<td></td>
<td>Fast</td>
<td>False positive results</td>
</tr>
<tr>
<td></td>
<td>High accuracy</td>
<td></td>
</tr>
<tr>
<td>Non-Contacted Meth.</td>
<td>Safe</td>
<td>Expensive</td>
</tr>
<tr>
<td>Computer vision with 3d-laser</td>
<td>Very fast</td>
<td></td>
</tr>
<tr>
<td>camera</td>
<td>Very high accuracy</td>
<td></td>
</tr>
</tbody>
</table>

A typical rail inspection application running based on computer vision includes the following steps respectively [7].

**Preprocessing:** It includes the steps of preprocessing the camera data that constitute the input of the system for noise removal and similar purposes.

**Feature Extraction:** It includes the processes of obtaining eigenvalue from large-scale camera data by feature extraction methods to operate real-timely.

**Learning:** It includes the step of training the data obtained in the previous step by machine learning algorithms.

**Test:** It includes the step of classifying the new data according to values learned by the system during training and generating diagnostic results during test or real-time inspection.

**Other:** It includes the operations such as the evaluation of other sensor data such as accelerometer, gyroscope and encoder to be used in the system, and recording all data for system confusion matrix extraction.

A study that includes the steps of calibrating the cameras, extracting three-dimensional rail profiles by taking data from cameras, obtaining eigenvalue on these profiles by feature extraction methods, and training and testing of the system by machine learning for a rail inspection application in which 2 three-dimensional laser cameras are used for the left and right surfaces of the rail line is presented in this paper.

II. 3D LASER CAMERAS AND GETTING 3D DATA

The standard cameras operating with sensors such as Ccd and Cmos give two-dimensional image on x-y plane. This image is called as three-dimensional if it includes the depth information on the z plane. The methods of *stereovision, time of flight* and *laser triangulation* are used in obtaining three-dimensional image [14].

Stereo vision technique is the same as the principle of human vision. It is based on the principle of finding the pixel distance by measuring the projections of each pixel on two separate cameras by geometric methods because the distance and angle between cameras are known in imaging which is performed using two separate calibrated cameras. Although it is low cost, the accuracy performances depend on calibration and the sensitivity of camera parameters [15].

Time of flight cameras containing both rgb camera and an infrared sensor get depth information as well as rgb information by measuring the flight time of the infrared waves. They are particularly used in applications such as game consoles, virtual reality and three-dimensional modeling. They have cost effective and low accuracy solutions [14, 15].

Another method used in obtaining three-dimensional image is the use of laser cameras. Laser cameras consist of a calibrated camera, laser line source, light source and encoder as shown in Fig. 3. These components are usually integrated products. The system builds up the three-dimensional profile of the object by benefiting from the profile change in the laser line via constantly taking pictures. The object needs to move in a controlled manner while performing the profiling process in moving objects with laser cameras. How much the object has moved is determined by means of an encoder.
The simple mathematical provision of the process of obtaining three-dimensional profile matrix by reading the rail profile can be given as in (1). “x_{cam}, y_{cam}” gives the coordinate information of the laser camera in the matrix, “x_i, y_i” gives the real coordinate information of the scanned rail surface “p,i” gives the information of the total number of profiles to be read and the sequence information coming from the encoder, respectively. The typical features of 3d-laser cameras by taking the sick presented in the study as a reference are presented in Table II [16].

\[
\sum_{i=1}^{P} p_i = \sum_{i=1}^{P} \sqrt{(x_{cam} - x_i)^2 + (y_{cam} - y_i)^2}
\]

### 3-D LAZER CAMERA FEATURES

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>10.000-35.000 Profile/Second</td>
</tr>
<tr>
<td>Resolution</td>
<td>1536 x 512 Pixel</td>
</tr>
<tr>
<td>Field of View</td>
<td>250 x1200 mm</td>
</tr>
<tr>
<td>3d resolutions</td>
<td>0.2 mm</td>
</tr>
<tr>
<td>Interface</td>
<td>Gigabit ethernet</td>
</tr>
<tr>
<td>Encoder frequency</td>
<td>2Mhz</td>
</tr>
<tr>
<td>Other</td>
<td>High-pass filter, vibration reduction</td>
</tr>
</tbody>
</table>

### III. PROPOSED METHOD

The test device and the block diagram of the proposed method conducted for the system are given in Fig. 4.

The proposed system works in four steps. In the first step, a test device that could carry the laser camera and the computer and move on the railway was developed. In the second step, a software providing the calibration of the camera and laser line source constituting the laser camera system was used with the purpose of obtaining three-dimensional profile. In the third step, pre-processing was performed on three-dimensional images obtained from the railway track; and three-dimensional railway profiles were obtained in the fourth step. The obtained three-dimensional railway profiles will constitute the input data of fault diagnosis algorithm.

### IV. EXPERIMENTAL RESULTS

In rail inspection operations conducted using three-dimensional laser cameras, the experimental results include the steps of calibrating the laser cameras and obtaining rail profiles by preprocessing the three-dimensional data obtained from the calibrated cameras. The obtained three-dimensional rail profiles will constitute the input data of the machine learning-based fault diagnosis algorithm.

In the next step, the eigenvalue was obtained on the rail profiles by feature extraction methods, and it was labeled as faulty and healthy to be used in training algorithm. The system was trained by using Random Forest (RF) which is a classification method using multiple decision trees [17].

It is one of the most suitable classification algorithms to be used in fault diagnosis since it functions rapidly even in large data sets, provides good results on lost data and generates high accuracy results.
The trained system was tested by measuring the operating speed and accuracy performance on a rail line for a short time in the test phase. A total of 400 rail profiles were collected on a 1 km-long rail line by the proposed system, and these profiles were trained by labeling as healthy and faulty. 75% of the dataset was used in training. The remaining 25% was used for testing purposes. 98% accuracy rate was achieved in the test phase. The receiver operating characteristic (ROC) analysis was used to obtain the accuracy performance values shown in detecting the "faulty" frames containing system anomalies and the "healthy" frames having no anomalies [18]. The roc curve obtained by the proposed method is given in Fig. 6.

V. CONCLUSIONS

Rail transportation systems are widely used around the world. The rail lines should be inspected periodically and their maintenance should also be performed to ensure the railway transportation safety. Today, this inspection process is commonly carried out using CVS. In this study, the software architecture is presented for a rail inspection conducted using 3-D laser cameras.

In general, there are three criteria expected from a rail inspection application. These are the high accuracy results, high operating speed and the cost of the system. 3-d laser cameras allow for obtaining higher accuracy rate in rail inspection because they include both RGB data and precise distance information that two-dimensional cameras have. When they are compared with normal cameras, their another advantage is that they are more susceptible to false positive result situations in oil and dust stains caused by image processing algorithms because they use distance information.

The second criterion expected in rail inspection applications is the high operating speed. Today, laser cameras are suitable for real-time operation on a real transportation device by their profile generation speed of 10,000-35,000 per second. The third success criterion expected in rail inspection applications is the cost of the system. High speed and accuracy rates can be obtained in applications using 3-d laser cameras, but their costs are higher. It is thought that this disadvantage is eliminated by their other advantages.

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Different Apple Varieties Classification Using kNN and MLP Algorithms

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Abstract—In this study, three different apple varieties grown in Karaman province are classified using kNN and MLP algorithms. 90 apples in total, 30 Golden Delicious, 30 Granny Smith and 30 Starking Delicious have been used in the study. DFK 23U445 USB 3.0 (with Fujinon C Mount Lens) industrial camera has been used to capture apple images. 4 size properties (diameter, area, perimeter and fullness) and 3 color properties (red, green, blue) have been decided using image processing techniques through analysing each apple image. A data set which contains 7 physical features for each apple has been obtained. Classification success rates and error rates have been decided changing the neuron numbers in the hidden layers in the classification made using MLP model and in different neighbour values in the classification made using kNN algorithm. It is seen that the classification using MLP model is much higher. While the success rate of classification made according to apple type is 98.8889%.

Keywords—Image processing, Apple classification, kNN, MLP

I. INTRODUCTION

Apple production is an important economic activity in Karaman. The dominant apple varieties produced in Karaman, are Golden Delicious, Granny Smith and Starking Delicious. During marketing these apples, the product is wanted to be consisted of just one species of apples. The mixture rate of other apple varieties in the product is wanted to be at minimum level. For this purpose many selection system have been proposed in the literature.

He Yong et al. (2007) have evaluated the potential of visible/near-infrared (Vis/NIR) spectroscopy for its ability to non-destructively differentiate apple varieties. The chemo metrics procedures applied to the Vis/NIR data were principal component analysis (PCA), wavelet transform (WT), and artificial neural network (ANN). The highest level of correct classification (100%) of the apple varieties have been achieved with WT-ANN model [1].

Ronald et al. (2016) have proposed to investigate the applicability and performance of Naive Bayes algorithm in the classification of apple fruit varieties. Apple classification system prototype was built using MATLAB R2015a development platform environment. The results showed that the averaged values of the estimated accuracy, sensitivity, precision and specificity were 91%, 77%, 100% and 80% respectively [2].

Wu et al. (2016) proposed a novel fuzzy clustering model, called fuzzy discriminant c-means (FDCM) clustering, to classify apple varieties couple with near infrared spectroscopy. The 200 apple samples of four apple varieties were made experiments to collect the near infrared reflectance (NIR) spectra. The clustering accuracy of FDCM achieved 97% which was higher than FCM, possibilistic c-means and Gustafson–Kessel (GK) clustering [3].

Shahin et al. (2013) have proposed to detect bruises in apples by using line-scan x-ray imaging method. Spatial and transform features were evaluated for their discriminating contributions to fruit classification based on bruise defects. Red delicious (RD) and golden delicious (GD) apples have been used in this study. Separate artificial neural network (ANN) classifiers were developed for old (one month) and new (24 hour) bruises. When an ANN classifier was used to sort apples based on old bruises, it achieved an accuracy of 90% for RD apples and 83% (93% after threshold adjustment) for GD apples. For new bruises, the accuracy was approximately 60% for both RD and GD apples. New bruises were not adequately separated using this methodology [4].

In this study, 90 apples grown in Karaman have been used. 7 morphological attributes have been obtained from their images by using image processing techniques. The apples have been classified into 3 group (Golden Delicious, Granny Smith and Starking Delicious) with kNN and MLP algorithms by using the obtained attributes.

II. MATERIALS AND METHODS

An interface presented in Figure 1, have been designed by using GUIDE (Graphical User Interface Design) in MATLAB. The image of the apple under the camera is taken when the Take Button pressed on the GUI.

The mean of R (red), G (green) and B (blue) pixel values of the area where the apple is in the image have been calculated. These values have been used for classification of the apples for their colors. Then the colored images have been converted to grey level image by using image processing techniques. Morphological operations have been applied onto bitwise images. The image processing steps have been presented in Figure 2.

Figure 2.
Fig. 1 Graphical user interface designed in MATLAB GUIDE.

Fig. 2 The image processing steps

The physical properties of the apple like radius, perimeter, area, volume, mass and eccentricity have been extracted. So that creates 7 attributes by gathering 4 morphologic and 3 colour.

A. Software-WEKA

Developed by Waikato University in New Zealand, WEKA is an open-source data mining software with a functional graphical interface which incorporates machine learning algorithms [5]. WEKA includes various data pre-processing, classification, regression, clustering, association rules, and visualization tools. The algorithms can be applied on the data cluster either directly or by calling via Java code [6,7]. They are also suitable for developing new machine learning algorithms.

1) Multilayer Perceptron: It is a feed forward type artificial neural network model which maps input sets onto appropriate output sets. A multilayer perceptron (MLP) is composed of multiple layers of nodes where each layer is connected to the next. Each node is a processing element or a neuron that has a nonlinear activation function except the input nodes. It uses a supervised learning technique named back propagation and it is used for training the network. The alteration of the standard linear perceptron, MLP is capable of distinguishing data which are not linearly separable [7].

2) K-Nearest Neighbour Algorithm: The k-NN is a supervised learning algorithm that solves classification problems. Classification is the examination of the attributes of an image and the designation of this image to a predefined class. The important point is the determination of the features of each category in advance [8]. According to the kNN algorithm used in the classification, based on the attributes drawn from the classification stage, the distance of the new individual that is wanted to be classified to all previous individuals is considered and the nearest k class is used. As a result of this process, test data belongs to the k-nearest neighbour category that has more members in a certain class. The most important optimization problems in the kNN method are the identification of the number of neighbours and the method of distance calculation algorithm. In the study, the identification of the optimum k number is performed with experiments, and the Euclidean Distance Calculations method is used as a distance calculation method. Euclidean calculation method [9]:

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xi and xj are two different points, and we need distance calculation process in between.

In classification procedure, inputs are diameter, perimeter, area, fullness, mean red, mean green and mean blue values. The outputs are Golden Delicious, Granny Smith and Starking Delicious. The whole classification system have been presented in Figure 3.

![Block Diagram of Classification Process](image)

**Fig. 3 The block diagram of the classification process**

### III. RESULTS AND DISCUSSION

In the study, WEKA software was used in order to classify apples by species (Golden Delicious, Granny Smith and Starking Delicious). Using the kNN algorithm, the classification success rates, mean absolute error (MAE) and root mean square error (RMSE) were obtained for various k-neighbour values. The classification success rates obtained with kNN algorithm, and MAE and RMSE values can be seen in Table 1. The success rate change versus number of neighbours for kNN method is presented in Figure 4.

<table>
<thead>
<tr>
<th>Neighbourliness Number (k)</th>
<th>Classification accuracy (%)</th>
<th>MAE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>93.3333</td>
<td>0.0414</td>
<td>0.1886</td>
</tr>
<tr>
<td>2</td>
<td>96.6667</td>
<td>0.2296</td>
<td>0.2854</td>
</tr>
<tr>
<td>3</td>
<td>97.7778</td>
<td>0.0364</td>
<td>0.1283</td>
</tr>
<tr>
<td>4</td>
<td>90.0000</td>
<td>0.0512</td>
<td>0.1537</td>
</tr>
<tr>
<td>5</td>
<td>94.4444</td>
<td>0.0543</td>
<td>0.1541</td>
</tr>
<tr>
<td>6</td>
<td>93.3333</td>
<td>0.0539</td>
<td>0.1500</td>
</tr>
<tr>
<td>7</td>
<td>95.5556</td>
<td>0.0546</td>
<td>0.1503</td>
</tr>
<tr>
<td>8</td>
<td>94.4444</td>
<td>0.0644</td>
<td>0.1573</td>
</tr>
<tr>
<td>9</td>
<td>94.4444</td>
<td>0.0728</td>
<td>0.1670</td>
</tr>
<tr>
<td>10</td>
<td>91.1111</td>
<td>0.0803</td>
<td>0.1735</td>
</tr>
</tbody>
</table>
The data in the same dataset were processed using the multilayer perceptron model, and the classification success rates, MAE and RMSE error values were obtained for various number of neurons in the hidden layer. In the multilayer perceptron model, the training was performed by taking the learning rate value as 0.3, momentum value as 0.2 and iteration number as 500. The classification success rates, and MAE and RMSE values obtained using the multilayer perceptron model can be seen in Table 2.

<table>
<thead>
<tr>
<th>The number of neurons in the hidden layer</th>
<th>Classification accuracy (%)</th>
<th>MAE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>94.4444</td>
<td>0.1975</td>
<td>0.2513</td>
</tr>
<tr>
<td>2</td>
<td>97.7778</td>
<td>0.033</td>
<td>0.0985</td>
</tr>
<tr>
<td>3</td>
<td>95.5556</td>
<td>0.0375</td>
<td>0.1350</td>
</tr>
<tr>
<td>4</td>
<td>96.6667</td>
<td>0.0352</td>
<td>0.1152</td>
</tr>
<tr>
<td>5</td>
<td>98.8889</td>
<td>0.1698</td>
<td>0.2225</td>
</tr>
<tr>
<td>6</td>
<td>97.7778</td>
<td>0.0355</td>
<td>0.1089</td>
</tr>
<tr>
<td>7</td>
<td>97.7778</td>
<td>0.0269</td>
<td>0.1049</td>
</tr>
<tr>
<td>8</td>
<td>97.7778</td>
<td>0.0223</td>
<td>0.1073</td>
</tr>
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<td>9</td>
<td>96.6667</td>
<td>0.0479</td>
<td>0.1234</td>
</tr>
<tr>
<td>10</td>
<td>96.6667</td>
<td>0.0441</td>
<td>0.1214</td>
</tr>
<tr>
<td>20</td>
<td>95.5556</td>
<td>0.0746</td>
<td>0.1476</td>
</tr>
</tbody>
</table>

The diagram demonstrating the changes in classification success rate based on the number of neuron in the hidden layer is demonstrated in Figure 5.

The model of MLP whose hidden layer consists of 5 neurons which creates the highest classification success rate is shown in Figure 6.

IV. CONCLUSIONS

In this study, classification of apples as Golden Delicious, Granny Smith and Starking Delicious have been proposed by using machine learning algorithms. The classification success rates and error values of data mining algorithms were calculated for kNN and MLP. It was observed that the success rate was higher for the classifications performed using the MLP algorithm. The highest classification success rate was achieved when the number of neighborhood was 3 and the success rate was 97.7778 %. The MAE and RMSE error value were 0.0364 and 0.1283 respectively. For the classification success rates obtained using MLP algorithm, the highest classification success rate and minimum MAE error value was achieved for 5 neurons in the hidden layer and it was 98.8889%. For this MLP structure, the MAE and RMSE error values were 0.1698 and 0.2225 respectively.
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Role of Ethics in Information Security

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Abstract—Information is power. Nowadays, main concern of cyber community is to protect this valuable asset. Technical and technological security measures are sometimes insufficient to protect an information system. Because there is a human factor in information system. Ethics are set of moral rules that guide people. With the help of ethics a better and robust security can be achieved. In this paper role of ethics in information security is discussed. First of all law, ethics and information security concepts are briefly introduced. Later, some ethical concerns and perspectives in information security are given. To emphasize role of ethics in information security, several studies are reviewed. Finally, mechanisms to make ethical rules effective in an organization/community are discussed with several case studies.

Keywords— Ethics, Ethical Issues, Information Security, Cyber Security, Information Systems.

I. INTRODUCTION

With the advance of Information Technology, new threats and unauthorized actions arise each day. To be able to protect information assets against these threats and actions is one of the most important issues nowadays. But sometimes technical and technological measures are not enough to protect an information system. One of these parameters is people. These people can be system administrators, security professionals, employees and users. These are the people that interact with information system. In order to secure people parameter in an information system, a measure that employs moral judgment must be introduced. Computer and information ethics are studied by many researchers, scholars and practitioners [1]. To include ethical layer to information security is very important because it can fill the gap that people create.

In this paper role of ethics in information security is discussed. First of all law, ethics and information security concepts are briefly introduced. Some ethical concerns and perspectives of several researchers in information security are given. To emphasize role of ethics in information security, several studies are reviewed. Mechanisms to make ethical rules effective in an organization/community are discussed. Finally, paper finishes with conclusions and references.

II. LAW & ETHICS

Laws are a form rules that prevent certain behavior and actions happen. They are created from ethical structures. The major difference between law and ethics is: law needs an authority to process and ethics don’t [2]. Ethical behavior comes from individual’s conscience. Ethics are defined in the light of a group’s cultural customs. But as in laws it’s different, many laws are universal across the world.

Laws are the rules that all of the people must oblige to follow. If they don’t follow, they will be punished. That’s not the case in ethics; in ethics all people have their own will. They can choose to follow or not follow code of ethics. In ethics, it depends on a moral decision, many people agree upon ethical behaviors but some people can disagree on these.

Ethics can be seen from different approaches. These approaches are consequentialism and deontological [3]. Consequentialism claims that if actions have bad consequences they are bad after all. Deontological approaches don’t think like that. They assume that actions of people have neither good nor bad consequences they have only moral duties independent of their actions.

There exists a blurrieness of ethics in individual’s mind but with the help of the laws and regulations security and safety can be achieved. In a cyber world, law and ethics work together to form a security layer. Ethics can fill the void where laws cannot be applied.

III. INFORMATION SECURITY

Rapid growing of information technology enables many organizations, government and civilians exchange important information every day. So security issues arise when sharing information [4]. Nowadays relationship of organizations depends on computer and information systems, many organizations are concerned about information security because they use technologies like e-commerce, mobile and virtual private networks. With the increase of involvement of these technologies, number of threats to organization’s valuable assets also increases [4]. Information security protects confidentiality, integrity, and availability of information assets against various threats. Technical protection measures are not enough to provide information security. There must be other measures. To develop a robust and good information security; in addition to technical measures; operational, ethical, sociological and legal measures must be considered [5].

Organizations depend on processes, technology and people. Even if we have top of the line information systems and security, there are people operating these information systems [4]. They control daily activities and thus the entire information system. They need to have moral and ethical conducts, if they don’t have these conducts they will make information system vulnerable to threats. There is no efficient technical protection of information security because people are involved [4]. People are critical on ensuring a robust
There are different ethical views in information security. Researchers proposed several models to achieve better information security.

Hartmann [8] stated that security levels couldn’t consist of only a technical layer. It consists of technical, technological, organizational, legal, social and ecological levels. In addition to these levels Hartmann suggests ethical scope must be included in information security. The researcher also suggests that ethics is a so large question that developers, users and system admins cannot answer separately. Entire community should answer this question by discussing together. So Hartmann suggests that ethics should span an entire community and ethical rules should be prepared with a mixture of individuals from different areas.

Another ethical view in information security is proposed by Kowalski [9]. Kowalski stated several ethical problems and also stated that information security is threatened if these problems occur in information technology systems. These problems are as follows:

- There is a control gap in information systems and it is getting wider with every new technology. This control gap can cause problems in retaining security in information systems.
- Ethics must be a common language among individuals from different expertise. Ethics should also understandable by individuals from other communities besides computer society.
- Nowadays information systems are getting so large that it is getting harder to manage with only technological control mechanisms. So control mechanisms should be built on individuals control mechanism that can be achieved by ethical frameworks.

If these problems don’t answered right there can be an opening that leads to information security issues.

As seen from given perspectives complete security of information can only be achieved by the help of ethics and ethical frameworks.

VI. FRAMEWORKS FOR ESTABLISHING AN ETHICAL BASELINE IN DIFFERENT ENVIRONMENTS

Many researchers stated that information security is lacking without an ethical concept. So in order to establish a better security, they proposed frameworks that include ethical principles. These frameworks exist in many information environments like biomedical, e-banking and health and etc. Example frameworks will be discussed in this chapter to emphasize the importance of ethical principles in information security.

France [10] discussed ethical violations in biomedical area that leads to violation of patient privacy and medical records. He also stated some ethical codes and suggestions to overcome this security issue. These ethical codes include doctor and hospital staff jurisdictions, patient record storage, etc.

Abreu and co-workers [11] discusses fraud (phishing) in e-banking services. They point out several threats, vulnerabilities, incidents and impact of threats on e-banking services. Researchers suggested ethical rules and trainings on clients and bank personnel to overcome frauds in e-banking services. They also stated that Public discussion on incidents will develop awareness and creates a security behavior among e-banking service users.

Kluge [12] developed a code of ethics for health information professionals. He discussed several problems in health informatics domain and proposed code of ethics for several information security problems. He suggested that in addition to technical security layer in a health information system there must be an ethical layer that protects privacy of patients. He created this ethical layer on health information professionals.

VII. MAKING ETHICAL RULES EFFECTIVE IN COMMUNITY

Making ethical rules effective in a community plays an important role in security of information. Being able to give
individuals a set of ethical rules to follow and provide an awareness of ethics will surely establish a better security layer in organizations. To provide a better and robust security of information, there are two ways: Developing a code of conduct/ethics and provide trainings to individuals so they can gain awareness in security and ethics.

A. Code of Conduct

Nowadays many organizations and communities develop code of conduct for its members to follow [13], [14]. Without the development of these codes information security will have gaps because of laws couldn’t fill some gaps and ethics can. For example; in order to fill these gaps, computer ethics institute developed Ten Commandments of Computer Ethics [15]:

1. Thou Shalt Not Use A Computer To Harm Other People.
2. Thou Shalt Not Interfere With Other People’s Computer Work.
3. Thou Shalt Not Snoop Around In Other People’s Computer Files.
5. Thou Shalt Not Use A Computer To Bear False Witness.
6. Thou Shalt Not Copy or Use Proprietary Software for Which You have Not Paid.
7. Thou Shalt Not Use Other People’s Computer Resources without Authorization or Proper Compensation.
8. Thou Shalt Not Appropriate Other People’s Intellectual Output.
9. Thou Shalt Think About The Social Consequences Of The Program You Are Writing Or The System You Are Designing.
10. Thou Shalt Always Use A Computer In Ways That Insure Consideration And Respect For Your Fellow Humans.

This code of ethics guides individuals when interacting with an information system. Code of ethics is applied to all of the members in an information system including system administrators, developers, users and security professionals. Instead of applying general code of ethics, organizations can develop their own code of conduct. In our opinion this can be prove to be most effective because to target and fill specific gaps in information security, specific ethical codes must be defined. But in order to make users abide code of ethics and to a standard there is a need for collaborative effort [16]. Awareness training helps to establish this collaborative effort.

B. Awareness Training

Awareness training and security training takes a major part in establishing security. In order to provide security there must be awareness among individuals. This awareness spans to a large definition including; ethics, threats and how to deal with them, security incidents and so on.

Awareness training must provide an appropriate security and ethics behavior to all individual in an organization in order to full commitment to security policies [17]. There are some research that focuses on awareness training and how it is effective in providing security. Stephanou and Dadaga [17] have asked the question “to what extent does information security awareness training influence information security behavior?” and they discuss existing awareness training research and proposed a model to examine the impact of training on security behavior among individuals.

Aliyu and co-workers [18] conducted a study that inspects security and ethics behavior among students. They conducted several experiments among students to find out that is awareness actually affects security. The experiments showed that the awareness training created a conscience of security among students. Because of security awareness trainings and ethics courses students are more aware of security concerns and ethics than the students who receive no training.

So according to these studies that we mentioned above, we can say that awareness training actually can affect the security behavior of individuals. Also they are crucial in making ethical rules effective in community. Because this training also gives a conscience of ethics to individuals and in our opinion is crucial to establish information security.

VIII. CONCLUSIONS

Ethics play an important role in our lives and also in cyber technology domain. Ethics fill gaps in an information system that laws can’t be able to fill. In this paper the importance of ethical principles in information security has discussed. Different ethical perspectives in literature are inspected to show how ethical layer can be built on security layer. Also in this paper, to provide a solid proof that ethics complete information security, several ethical frameworks are inspected. Finally, methods to make ethical rules effective in a community are given. Several examined studies showed that awareness training and code of conducts are effective in this manner.

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Knowledge Mining Approach For Healthy Monitoring From Pregnancy Data With Big Volumes

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Abstract— The process for obtaining information that will create value on a large-scale data stack is called data mining by its general name. Data mining is commonly used in sales and marketing departments, in determining strategies and making critical decisions for the future in many sectors. Similarly, data mining is used in the determination of health policies, more effective implementation of health services and in the management of resources and institutions in the health sector.

In this study, it was aimed to create a software architecture of data mining that will help the personal monitoring of the pregnancy process in a more effective way in the health sector. Many different types of data such as age, gender, location, education, physical characteristics, lifestyle habits and medical history of the people that could be used for this purpose are stored online by health institutions. The machine learning algorithms have been created to determine classification, clustering and association rule on these data.

Keywords— Data Mining, Knowledge Mining, Health Monitoring, Classification, Clustering, Machine Learning, Association Rule

I. INTRODUCTION

The data generated by the computer systems do not make a sense by themselves, and their conventional analysis by human intervention is also impossible. Today, the diversity of data generated in fields such as stock market, trade, education, communication and e-commerce in addition to the fact that these data are large by volume and continue to increase are the main reasons of this.

In today's world, obtaining valuable information by interpreting these data by means of intelligent algorithms is called data mining. In other words, data mining is the discovery and interpretation of the significant relationships through computer programs that could be effective in providing future predictions from among large data stacks [1, 2].

Data mining has a great importance in many aspects from sales strategy of businesses to determination of Research and Development activities.

The analysis and interpretation of large-scale data and uncovering the relationships between data are difficult and long processes by human labour and talent. Today, performing knowledge retrieval using data mining is commonly used in many fields such as marketing, banking, stock market, communication systems, education, health and engineering.

In the marketing field, an attempt to bring out user patterns using data mining was made by Ünal et al. in order to determine the customer portfolio and to describe the user's shopping behaviors by using data of an internet retailer [3].

In the banking field, Tosun et al. tried to determine the customer losses and the reasons of the losses by constructing the profile of the 30,000 customers of Yapı Kredi Bank [4].

Between the years 2007-2013, Ocal et al. used data mining to make a qualitative classification according to the financial success or failure of the companies and the capacity situations of the companies by using the data of Borsa İstanbul [5].

A large telecommunication company's customers who showed a tendency to leave were determined by Gürsoy in 2010, and new campaigns for these customers and marketing strategies for the customer profile were developed by classification method [6].

In the research carried out by Gülen at al. on gifted children aged 7 years and older in Ankara science and art center, the education for the children's individual needs was differentiated through educational data mining and the course schedules were organized according to children's field of interest [7].

In the engineering field, Kaya et al. compared the open source data mining softwares Keel, Knime, Orange, R, RapidMiner (Yale) and Weka. In the study, which data mining method and which software would be more effective on which data set was investigated [8].

Tantuğ et al. examined the techniques used in data mining and especially investigated the clustering techniques. An efficient software architecture to reduce memory complexity was designed in the study. An efficient system with a lower complexity capable of clustering on large-scale data was developed by the software architecture designed [9].
The healthcare field is among the extensive areas of usage of data mining. Ertuğrul et al. constructed the patient profiles by processing and using the data in the patient information management system of Pamukkale University Hospital. Based on the patient profile information, healthcare professionals established a decision support system to provide taking most objective and effective decisions about the patient by reaching up-to-date information about the patient [10].

İrmak et al. processed the patients' information in the database of a hospital continuing to provide services via data mining techniques and developed an application for estimating the patient density of the hospital in the future [11].

By descending to particulars, in the applications in the field of health, Yıldız et al. developed an application that classifies the breast cancer types by using gene algorithm and data mining about breast cancer [12].

In this study, it was aimed to build software architecture of data mining for the effective personal follow-up of women during their pregnancy period.

Many different types of data such as the age, gender, location, education, physical characteristics, lifestyle habits and medical history of the pregnant could be collected and processed with data mining techniques.

Thus, the control frequency could be determined according to the personalized care, nutrition content, situations that require education and risk status during pregnancy by the expectant mothers' data interpreted. Consequently, an approach that uses data mining in following the pregnancy process was proposed in the study.

II. DATA MINING

As a general definition, data mining is the process of mining information by reaching the information from among large-scale data. With another definition, it is to search for the connections that could allow us to make predictions for the future from among the large-scale data stacks using computer programs [13].

In almost every stages of our life, electronic recording systems such as mobile phones, sensors and computers provide convenience for recording and storing information and reaching them where necessary along with the technological developments. To be able to make sense out of these data which are rapidly increasing by volume, to establish relationships by them and to finalize data by a decision or conclusion have led researchers to carry out much more investigations in the field of data mining.

Several processes and some techniques are used while performing data mining studies independently of the problem [13, 14]. These processes involve the use of data cleaning, data integration, data reduction, data conversion and data mining algorithms and ultimately the interpretation of the obtained results and the steps of verifying these results, respectively [15].

In general, the steps of retrieving significant knowledge on a purpose-specific data set are presented in Fig. 1. Data mining processes consisting of six steps are presented in Table I.

![Fig. 1 Data mining process](image)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Cleaning</td>
<td>The bad and inconsistent data found in the database are called noise. These data can exit the process or the processing can be performed by setting a fixed value instead of them. This is called data cleaning.</td>
</tr>
<tr>
<td>Data Integration</td>
<td>It is the process of combining different types of data taken from different databases by converting into a single data type.</td>
</tr>
<tr>
<td>Data Reduction</td>
<td>The number of data or variable can be reduced by numerous data reduction methods such as data compression, merging, sampling and generalization.</td>
</tr>
<tr>
<td>Data Conversion</td>
<td>It is the process of changing the format of the data by protecting its content according to the algorithm model to be used.</td>
</tr>
<tr>
<td>Application of Data Mining Algorithms</td>
<td>It includes the processes of applying machine learning algorithms on data which were made ready through the above processes for classification, clustering or determining the association rule.</td>
</tr>
<tr>
<td>Interpretation and Verification</td>
<td>The data on which algorithm was applied are verified by bringing out certain significance relationships.</td>
</tr>
</tbody>
</table>

There are three main methods of data mining to make interpretation and verification [15, 16]. These methods are called as classification, clustering and determining the association rule,

1) Classification: It is one of the fields where data mining is commonly used. People often adopt this method because they always classify, categorize or grade the data. Rules are determined by keeping some of the data found in the database separate for education, and how to decide when a new situation arises is determined by this rule.

2) Clustering: It is the process of grouping data by taking into account the similarities between them. By this method,
clusters and sub-clusters are generated based on the similarities and differences between variabilities.

3) Determining the Association Rule: It is a data mining method which is applied on the possibility of which situations can occur simultaneously by identifying the relationships of the data included in the database with each other.

III. PROPOSED METHOD

In this study, expectant mothers’ information shown in Fig. 2 were used and the process of knowledge retrieval was performed using data mining on these data.

The software architecture of the proposed method, the block diagram of which is given in Fig. 2, works in four stages. In the first step, a no-sql based database was created for storing data. In the second step, preprocessing was performed to extract information on data set. In the third step, classification, clustering and association rule were identified by running three separate data extraction algorithms. In the fourth and final step, estimation on new data, identifying the cluster to which it belongs and the process of finding the other data to which it is related were performed.

In the study, expectant mothers’ information shown in Fig. 2 were used and the process of knowledge retrieval was performed using data mining on these data. The sample training set, main data types and the normalization of the data type into a certain range if necessary are given in Table II.

All values shown in Table II were converted to integer numbers by normalization, if needed, depending on the primary data types. The values of the sets obtained after normalization constituted the input data of the training algorithm. According to what some values are normalized is explained as follows.

- Body mass index: It is a value calculated based on height and weight, and it is divided into 3 groups in practice [17].
- Age: It is normalized to 3 different groups by considering the fertility criteria [17].
- Disease: Whether the person has a disease is discussed as a Boolean value.
- Pregnancy History: It includes the statistics of the person’s pregnancy history, if available. They are numerical data such as the number of children if she had a baby, whether the previous pregnancies were concluded with healthy results, cesarean and the number of normal delivery.

Matlab and python (scikit library) are mostly used for data mining studies in computer environment. In addition to these, there are also various tools which are free and open source and also include sample data-sets [8, 19]. However, a data-set was generated in a synthetic dataset matlab environment in accordance with Table II because there was not any dataset specific to this study, and it was saved in json format as no-sql based.

In the sample application scenario, random forest for classification and k-means for clustering were used [18]. The target class labels chosen for classification in the training algorithm were identified as “healthy pregnancy” and “risky pregnancy”. In the test phase, the results were analyzed by achieving classification accuracy according to “1” based on the confusion matrix given in Table III.
Accuray = \frac{TP + TN}{N} \quad (1)

IV. EXPERIMENTAL RESULTS

In the study, classification was performed on the synthetic dataset generated in a Matlab environment by random forest method. 75% of the dataset was used in training. The remaining 25% was used for testing purposes, and the results were compared on confusion matrix by comparing with actual values. The classification accuracy performance was above 80% in the scenario chosen for the sample classification application.

<table>
<thead>
<tr>
<th>Predicted</th>
<th>Actual</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>210</td>
<td>55</td>
</tr>
<tr>
<td>N</td>
<td>45</td>
<td>190</td>
</tr>
</tbody>
</table>

V. CONCLUSIONS AND FUTURE WORK

Today, data mining is commonly used with the purpose of obtaining valuable information in fields such as banking, education, sales, stock market and health. The information obtained as a result of data mining are effective in making strategic decisions.

In this study, it was aimed to perform pregnancy follow-up process using data mining in the follow-up process of pregnancy and retrieve information related to this process. Thanks to the proposed method, it was aimed to use these information in the pregnancy periods of new expectant mothers. The classification application was performed by creating a sample scenario for the study.

In addition to the study, it is aimed to create other similar scenarios in the future and make comparison with other open source tools used for performing data mining.

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Energy Efficient Random Selected Constant Clustering Approach for Wireless Sensor Networks

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Abstract — Nowadays, extending the lifetime of WSNs through energy efficient mechanisms has become a challenging research area. Previous studies have shown that instead of implementing direct transmission or multi-hop routing, clustering is a kind of fundamental technique used to decrease energy consumption. Clustering can increase the scalability, decrease the energy consumption and prolong the lifetime of the network. In literature, LEACH and its variants aim to use clustering mechanisms to provide energy-efficiency. However, most of the LEACH variants aim to form clusters in each round by changing CHs randomly. These formations cause to consume large amount of energy and bring additional network costs. Also, in some rounds of LEACH variants none cluster formations may occur because of the probabilistic CH selection process of these protocols. In this paper, an energy-efficient random selected constant clustering approach is proposed to solve the problems of LEACH based protocols. The proposed approach uses constant clusters which are formed only once at the beginning of the algorithm. The formed clusters remain fixed until all nodes are dead in the network. Proposed approach aims to select CHs in each cluster randomly without changing the cluster formations. It aims to reduce cluster formation packet overhead in the network. In addition, proposed approach aims to provide energy-efficiency by using fixed clustering. The results of the simulations show that, constant clustering approach saves extra energy and prolongs lifetime of the WSN when compared to LEACH and ModLEACH.

Keywords— Energy Efficient Routing, Fixed Clustering, Wireless Sensor Networks.

I. INTRODUCTION

A WSN contains sensor nodes and corresponding protocols for routing messages in this network. A typical wireless sensor node includes a sensory unit, a communication unit, a power unit and a processing unit. Sensory unit consists of a data acquisition component and ADC (converts the sensed real world data to the digital form). Communication unit has a radio transceiver and the power is backed by a battery source. The WSN node can be equipped with a limited power source (0.5 Ah, 1.2 V). The node remains active as long as the battery is alive and hence power saving is a crucial criterion in this domain of applications. Energy consumption happens in three domains: sensing, data processing and communications. The sensing, signal processing parts operate at low sequential and consume less than 1mW. This is over an order of extent less than the energy consumption of the communication part.

The traditional infrastructure based protocols cannot be used for WSNs because of the limited storage and power of the sensor nodes. Because WSNs often use broadcast based radio communication.

Limited energy availability in sensor nodes makes network lifetime an important issue in WSN applications. To extend the network lifetime, energy efficient wireless sensor network protocols and algorithms have been devised in the literature. Node clustering, in-network data processing, data fusion and network coding are some of the measures taken to reduce the amount of data that is processed, sensed or transmitted. Minimization of energy spent in processing, sensing and transmission of data allows sensor nodes to save energy. Such energy savings help to extend the lifetime of WSN applications.

The main goal of cluster-based routing protocol is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a cluster and by performing data fusion in order to decrease the number of transmitted packets to the base station (BS) and transmission distance of sensor nodes.

Low energy adaptive clustering hierarchy (LEACH) [1-2] is one of the most popular distributed cluster-based routing protocols in WSNs. LEACH randomly selects a few nodes as CHs which aggregate data arriving from nodes and forward the aggregated data to BS and rotates this role to balance the energy consumption of the sensor nodes in the network.

In LEACH protocol, the time is divided into parts called a round. Each round consists of two phases. The first phase is setup phase which is the phase of node formation. The second phase is related to the normal function of the network and is called the Steady-State phase. In the first phase, the CHs are elected based on a probability function. This election is as follows: each sensor node selects itself to be CH at any given time with a certain probability. Any node in the network chooses a random number between 0 and 1. Then this number is compared with threshold limit, if the number is less than a threshold, the node becomes a CH for the current round. This probability function is designed in such a way that within a specific number of rounds each sensor becomes a CH only once and thus the energy consumption is distributed over the whole network. After the set up phase of the round, where the CHs are elected, each CH announces its election to other nodes and each node chooses a suitable (nearest) CH for itself; and then it announces this decision to the related CH and thus the clusters are formed and the network comes into the steady-state
operation i.e data transmission. Then each CH creates a TDMA schedule in each cluster to organize the communication among cluster members. When the non CH nodes receive the TDMA scheme, nodes send their data to the CH once per frame during their allocated transmission TDMA slots. This allows the radio components of each non-cluster-head node to put the sleep mode at all times except during its transmit time, thus minimizing the energy dissipated in the individual sensors. After a certain amount of frames i.e. a TDMA round, the network re-elects CHs and re-form clusters. Then CH, after combining all the received data, will send the results to the BS. Besides, to prevent the interaction of the transmissions which occur in clusters at the same time, LEACH uses different CDMA codes. Existing CH chooses randomly a unique code from a list of spreading codes. The CH filters all received energy using this spreading code. Consequently, the radio signals of the neighbouring nodes are filtered out hence interference of the transmission of the nodes is minimized.

In some studies, authors have tried to improve the performance of LEACH. They have designed some protocols which made extensions to LEACH.

Modified LEACH (ModLEACH) [3] includes an efficient CH replacement scheme and dual transmitting power levels. The amplification energy is set to be the same for all kinds of transmissions in LEACH. But with ModLEACH, low energy level is used for intra cluster communications. Multi power levels are used to reduce the packet drop ratio, collisions and interference from other signals. When a node becomes a CH, the routing protocol in ModLEACH informs it to use high power amplification and when a node becomes a regular cluster member, the mode of that node becomes low level power amplification mode. Threshold based CH changing mechanism is used in ModLEACH to provide more efficient CH replacement. If the energy of the existing CH is higher than the threshold it continues to act as a CH if not a new CH for that cluster is elected and the cluster is formed again. Simulations of ModLEACH show that, ModLEACH outperforms LEACH in terms of throughput, network lifetime and CH formation.

In this paper, Energy Efficient Random Selected Constant Clustering Approach (EERCCA) is presented. It aims to use fixed clustering approach. It determines CHs randomly at the beginning of the algorithm. The formed clusters remain constant until the batteries of all sensor nodes are drained. In each round, the CHs are changed randomly but the clusters remain fixed. EERCCA aims to solve the network cost issues which occur in new cluster formations of LEACH based protocols. The performance of EERCCA algorithm is compared with LEACH and ModLEACH in terms of lifetime, residual energy and throughput.

II. EERCCA ALGORITHM

At the beginning of EERCCA algorithm, the sensor nodes are randomly deployed in a field as shown in Fig. 1. EERCCA algorithm starts with the CH selection process. The CHs are selected randomly at the beginning of the algorithm. The clusters are formed only once in the clustering phase. The fixed clustering approach of EERCCA provides to decrease the networking and set-up costs of LEACH based protocols. The nodes in the network are static, thus transmission of position information is realized only once.

When the CHs are selected, they broadcast CH notification messages to the WSN. Each cluster member joins nearest cluster. After this joining process, the clusters are formed. In each cluster, CH is responsible for receiving data from its members. When data collection is completed, each CH delivers collected data to the BS which is placed outside of the sensor field. In EERCCA, each CH node selects randomly new CH node from alive members in the cluster for every round. After this selection, new elected CH starts to collect data from cluster members. Then this new selected CH transmits the collected data to the BS.

III. SIMULATION ENVIRONMENT AND PARAMETERS

The simulations are conducted in MATLAB. 100 sensor nodes are randomly deployed in a 100 m x 100 m field as shown in Fig. 1 and BS is placed outside of the sensor field which have coordinates of (150,50). Same simulation parameters of LEACH are used for all simulations in this paper. Each simulation is realized for 100 independent iterations to obtain more scalable results. Table I summarizes the simulation environment parameters used for simulations.

![Fig. 1. The randomly deployed sensor nodes in a WSN.](image-url)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network area</td>
<td>100 m x 100 m</td>
</tr>
<tr>
<td>Number of nodes</td>
<td>100</td>
</tr>
<tr>
<td>Base station coordinates</td>
<td>(150,50)</td>
</tr>
<tr>
<td>Initial energy per node</td>
<td>2 J</td>
</tr>
<tr>
<td>Data packet size</td>
<td>6400 bits</td>
</tr>
<tr>
<td>Control Packet Size</td>
<td>200 bits</td>
</tr>
<tr>
<td>Transceiver Energy (E_{total})</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Aggregation Energy per Bit (E_{bits})</td>
<td>5 nJ/bit/signal</td>
</tr>
<tr>
<td>Free Space Amplifier Energy (E_{fs})</td>
<td>10 pJ/bit/m²</td>
</tr>
<tr>
<td>Multipath Amplifier Energy (E_{mp})</td>
<td>0.0013 pJ/bit/m²</td>
</tr>
</tbody>
</table>

TABLE I. SIMULATION ENVIRONMENT PARAMETERS
IV. SIMULATION RESULTS

In this section, the performance comparisons of LEACH, ModLEACH and EERCCA protocols are made for residual energy, number of alive nodes, lifetime and throughput. To obtain more scalable results, 100 iterations are realized. For each iteration, the average values of the results are collected.

A. Residual Energy

Fig. 2 illustrates the total residual energy of the nodes in terms of rounds. With fixed clustering, it can be observed that EERCCA provides significant energy savings when compared to LEACH and ModLEACH. After 2500 rounds, while LEACH holds 5% of its initial total energy, EERCCA holds approximately 20% of their initial total energy. When the network lifetime ends under LEACH, EERCCA still saves approximately 5% of its total initial energy. EERCCA also outperforms ModLEACH in terms of energy-efficiency.

Fig. 2. Comparison of Total Residual Energy

B. Number of Alive Nodes

Fig. 3 shows the number of alive nodes for LEACH, ModLEACH and EERCCA. In EERCCA network, the network lifetime increases from 3000 rounds to 4500 rounds, approximately 50% improvement compared to LEACH. EERCCA algorithm provides longer lifetime when compared to LEACH and ModLEACH because it does not change cluster formations for every round. It gets rid of transmitting of cluster formation messages in the network. It does not consume energy for broadcasting cluster joining messages in the network.

Fig. 3. Round Number vs Alive Nodes

C. Network Lifetime

For each algorithm, the simulations are repeated 100 times for different topologies and the maximum and average observed lifetimes are presented in Table II as well as the initial network energies. DEEC’s conservative energy consumption ratio increases the lifetime of a WSN significantly. DEEC outperforms LEACH and SEP.

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>Average Lifetime</th>
<th>Maximum Lifetime</th>
<th>Initial Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>EERCCA</td>
<td>4112</td>
<td>4471</td>
<td>200 J</td>
</tr>
<tr>
<td>ModLEACH</td>
<td>3742</td>
<td>4123</td>
<td>200 J</td>
</tr>
<tr>
<td>LEACH</td>
<td>3478</td>
<td>4216</td>
<td>200 J</td>
</tr>
</tbody>
</table>

D. Throughput

The cumulative number of packets transmitted to the BS per round is plotted in Fig. 4. With fixed clustering, EERCCA can continuously collect data for every round to send to the BS. On the other hand, due to the probabilistic CH selection mechanism, LEACH based algorithms cannot form clusters for some rounds. As a result, the throughput of EERCCA is significantly better than the compared protocols. This exact cluster formation structure of EERCCA provides to collect information from any part of the network at any time.
V. CONCLUSIONS

Nowadays, providing energy-efficiency, prolonging battery life span of the sensor nodes and designing green network components [4, 5] for WSNs has become a promising research area. By using constant cluster formations, EERCCA minimizes the cluster formation overhead. When compared with LEACH and other protocols significant improvements are achieved in terms of energy usage, network lifetime and throughput. EERCCA prolongs the lifetime of the WSN, while reducing the energy usage. Also, the throughput performance of EERCCA makes it more possible candidate to be used in critical applications such as fire rescue, earthquake measurements and disaster relief.

References

Network Traffic Classification by Kernel Based Extreme Learning Machine

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Abstract— The classification of data on the internet in order to make internet use more efficient has an important place especially for network administrators managing corporate networks. Studies for the classification of internet traffic have increased recently. By these studies, it is aimed to increase the quality of service on the network, use the network efficiently, create the service packages and offer them to the users. The first classification method used for the classification of the internet traffic was the classification for the use of port numbers. This classification method has already lost its validity although it was an effective and quick method of classification for the first usage times of the internet. Another classification method used for the classification of network traffic is called as load-based classification or deep packet analysis. This approach is based on the principle of classification by identifying signatures on packets flowing on the network. Another method of classification of the internet traffic which is commonly used in our day and has been also selected for this study is the kernel based on extreme learning machine based approaches. In this study, over 95% was achieved accuracies using different activation functions.

Keywords— machine learning, classification, extreme learning machine, network classification, kernel activation function

I. INTRODUCTION

Traffic classification methods are used to provide the efficient realization of the data traffic on network resources, to do user analysis by using network data, to manage and plan network resources, to detect the attacks and the abnormalities on the network [1, 2]. Recently, the network traffic classification has been frequently used in order to improve service quality in big networks [3, 4], use the network effectively, develop new service packets and perform internet traffic analysis [5]. Internet traffic analysis can be done both on-line and offline. In the on-line traffic analysis, each data packet on the network are captured and analysed [6, 7]. In the offline traffic analysis, network traffic flow is firstly captured and stored; then the stored flow is analysed and classified [8]. In this paper, offline traffic analysis was performed. In the literature, three kind of classification technique, including port, payload and machine learning based, have been used.

Port based classification is performed by comparing the port information retrieved from flow data with the port numbers of protocols determined by Internet Assigned Numbers Authority (IANA) [9]. For instance; port 80 is used for http, and port 23 for telnet traffic. Especially with the widespread use of point to point (P2P) applications, this method has started to lose his functionality as some applications use non-standard port numbers to escape from firewall and network security tools and some use port hiding and dynamic port methods [10-13]. Payload based classification is based on the principle of Internet traffic classification by analysing TCP/UDP packet loads. The analysis of loads is performed by determining whether the known applications contain characteristic signatures [10, 14].

When the packets are not encrypted, it works quite successfully. However, because of the following reasons, this classification technique is not much preferred today:

- It causes privacy and security concerns,
- Some applications communicate by using encrypted packets,
- It can only make assessment based on the signatures which are experienced by the previous classification methods,
- As it requires high processing and storage capacity, it is not suitable for real-time classification [11-13].

The network classification method via machine learning algorithms is the most popular traffic classification method at the present time. In the studies, the classification is usually performed using supervised and unsupervised learning algorithms. Supervised learning algorithms perform classification by using the classification analysis methods in data mining; and unsupervised learning algorithms perform classification by using the clustering analysis methods. Machine learning algorithms perform the process of network traffic classification in two steps. In the first step, it forms a classification model; and in the second step, it performs the classification. Statistical methods and calculations are usually utilized when performing the classification process.

Machine learning based classification method uses the following TCP and UDP statistical attributes of the flow during the flow-based classification:

- Total size statistics,
- Total number of forward and backward packets,
- Total amount of forward and backward byte,
- The transit time between packets,
- And flow time.

There are many studies on the field of Internet traffic classification by using machine learning. In their study, L.
Yingqiu et al. tried to classify network traffic on the original and log-transformed data set by using K-means algorithm [13]. In J. Erman’s study, clustering algorithms of AutoClass, K-means and DBSCAN, were used [15]. S. Zander performed network classifications by applying Exception Maximization (EM) algorithm and method of attribute selection on WAND Research Group’s open data sets and different data sets [16]. S. Zander et al. and S. Agrawal et al. made comprehensive comparisons about classification algorithms by using algorithms and attribute selection methods like C4.5, Bayes Net, Naïve Bayes [16-20]. Apart from port, payload, and machine learning based classifications in the literature, T. Karagiannis et al. developed an important classification method by using host service providers instead of TCP and UDP protocols [21]. L. Bernaille et al.’s classification technique which was performed by using unsupervised learning method and checking only the first few TCP packets is among the important studies in the literature [22]. Recently, ELM pattern recognition, which was suggested by Huang et al., has aroused great interest in the fields of machine learning and data mining; and a lot of applications have been performed regarding the issue [23-25,35]. ELM was suggested as a newly learning algorithm for Single-hidden Layer Feedforward Neural Networks (SLFNs) [23, 27]. During the learning process, SLFNs refreshes network loads based on the gradient. However, in ELM, input sizes and biases are random selected, and output sizes are calculated with an analytical method contrary to SLFNs. In this case, ELM gains the advantages of a fast learning process, a good generalization performance and a low computational load [27-29]. A higher accuracy percentage was obtained with Tangent sigmoid and triangular basis among activation functions which were used for the classic ELM algorithms in this paper. With kernel based extreme learning machine algorithm, which used Radial basis and polynomial activation functions rather than classic ELM, the accuracy percentage was observed to be even higher. In this paper, Internet traffic classification process has been shown using KELM faster and high accuracy.

In the second part of this paper, working principles of ELM algorithms were mentioned. The third part of the paper mentioned how the data was obtained and which data were used for the classification in experimental studies. In addition, different classification algorithms were compared.

II. EXTREME LEARNING MACHINE

Extreme Learning Machine was recommended in G.B.Huang et al. [28-31]. ELM used from 2004 onwards for training the Single-hidden Layer Feedforward Neural Networks (SLFNs) [23, 24]. Dissimilar from the extensive understanding of training SLFNs, ELM employs randomize computational nodes in the hidden layer and computes its output weights analytically by solving a general linear system equation. Later, ELM theory was extended to the “generalized” SLFNs, where the hidden nodes need not be neuron alike. Fig.1 shows the generic architecture SLFNs.

Given $N$ arbitrary training examples $\{(x_j,t_j)\}_{j=1}^N \subset \mathbb{R}^d \times \mathbb{R}^m$, the output of the generalized SLFNs with $L$ hidden nodes can be obtained as:

$$f(x_j) = \sum_{i=1}^{L} \beta_i g_i(x_j)$$  \hspace{1cm} (1)

$$f(x_j) = \sum_{i=1}^{L} \beta_i G(a_i,b_i,x_j) = o_j, j = 1,\ldots,N$$  \hspace{1cm} (2)

If the SLFNs can approximate all the $N$ samples without error, that is

$$\sum_{j=1}^{L} \|o_j - t_j\| = 0$$  \hspace{1cm} (3)

There exist pairs of $(a_i,b_i)$ and $\beta_i$ such that:

$$\sum_{i=1}^{L} \beta_i G(a_i, b_i, x_j) = t_j, j = 1,\ldots,N$$  \hspace{1cm} (4)

The above $N$ equations can also be equivalently expressed in the compact matrix form

$$H\beta = T$$  \hspace{1cm} (5)

Where

$$H = \begin{bmatrix} G(a_1, b_1, x_1) & \cdots & G(a_L, b_L, x_1) \\ \vdots & \ddots & \vdots \\ G(a_1, b_1, x_N) & \cdots & G(a_L, b_L, x_N) \end{bmatrix}_{N \times L}$$  \hspace{1cm} (6)
of ELM based on Mercer's conditions can be defined as follows

\[
\beta = \begin{bmatrix} \hat{\beta}_1^T \\
\vdots \\
\hat{\beta}_L^T \end{bmatrix}, \quad T = \begin{bmatrix} t_1^T \\
\vdots \\
 t_N^T \end{bmatrix}_{N 	imes m}
\]  

(7)

\[H\] is called the hidden-layer output matrix of the SLFN. \(\beta\) is represents the output weight matrix, \(T\) is the matrix that consists of output labels for the \(N\) data samples.

To train a SLFNs as mentioned in (2), it is equivalent to finding the least-square solution \(\hat{\beta}\) of linear system (5), that is:

\[\|H\hat{\beta} - T\| = \min \beta \|H\beta - T\| \tag{8}\]

In the case that the number of hidden nodes \(L\) is coequal to the number of different training samples \(N\), it is possible to find a \(\hat{\beta}\) such that the training error reaches zero. The hidden layer output \(H\) is an invertible square matrix. Hence the solution of the linear system can be given as:

\[\hat{\beta} = H^{-1}T \tag{9}\]

In the case that the number of hidden nodes \(L\) is less than the number of distinct training samples \(N\), to achieve the smallest training error \(\|H\beta - T\|\), the solution of the linear system (5) can be obtained as:

\[\hat{\beta} = H^{\dagger}T \tag{10}\]

Where \(H^{\dagger}\) is called the Moore-Penrose universalized inverse [32].

The least squares solution of (8) based on Karush-Kuhn-Tucker (KKT) conditions can be written as

\[\hat{\beta} = H^{\dagger}\left(\frac{1}{C} + HH^T\right)^{-1}T \tag{11}\]

where \(H\) is the hidden layer output matrix, \(C\) is the regulation coefficient, and \(T\) is the expected output matrix of samples. Then, the output function of the ELM learning algorithm is

\[f(x) = h(x)H^{\dagger}\left(\frac{1}{C} + HH^T\right)^{-1}T \tag{12}\]

If the feature mapping \(h(x)\) is unknown and the kernel matrix of ELM based on Mercer’s conditions can be defined as follows [33]:

\[M = HH^T : m_{ij} = h(x_i)h(x_j) = k(x_i, x_j), \tag{13}\]

Thus, the output function \(f(x)\) of the kernel based ELM can be written compactly as

\[f(x) = \left[k(x_i, x_1), \ldots, k(x_i, x_N)\right]\left(\frac{1}{C} + M\right)^{-1}T \tag{14}\]

Where \(M = HH^T\) and \(k(x, y)\) is the kernel function of hidden neurons of single hidden layer feed-forward neural networks. There are many kernel functions satisfying the Mercer’s condition available from the existing literature, such as linear kernel, polynomial kernel, Gaussian kernel, and exponential kernel. In this paper, we use Radial Basis (RBF) and Polynomial kernel function for performance analysis.

III. EXPERIMENTAL STUDIES

Moore et al [34] used the data received from the Cambridge University campus in this study. The most important factor in this selection is to enable to make comparison of studies previously carried out by using these data with the methods used in this study. One of the important factors is the use of data having flows belonging to different classes. In addition, the use of existing data that everyone can reach will provide a basis to get more reliable results.

12 features were chosen from output data. The chosen features and their explanations are illustrated in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Server port</td>
</tr>
<tr>
<td>2</td>
<td>Client port</td>
</tr>
<tr>
<td>3</td>
<td>Actual data packets (from client to server)</td>
</tr>
<tr>
<td>4</td>
<td>Pushed data packets (from client to server)</td>
</tr>
<tr>
<td>5</td>
<td>Pushed data packets (from server to client)</td>
</tr>
<tr>
<td>6</td>
<td>Min segment size (from client to server)</td>
</tr>
<tr>
<td>7</td>
<td>Average segment size (from server to client)</td>
</tr>
<tr>
<td>8</td>
<td>Initial windows bytes (from client to server)</td>
</tr>
<tr>
<td>9</td>
<td>Initial windows bytes (from server to client)</td>
</tr>
<tr>
<td>10</td>
<td>RTT samples (from client to server)</td>
</tr>
<tr>
<td>11</td>
<td>Median data IP(from client to server)</td>
</tr>
<tr>
<td>12</td>
<td>Variable data wire (from server to client)</td>
</tr>
</tbody>
</table>

Among the classes belonging to the flows, 7 most commonly used ones were chosen; and 1000 learning processes and 750 tests were applied to each class. Totally, 7000 classes were chosen for the learning process and 5250 for the test. Chosen classes are illustrated in Table 2.
The success measurement of classification by machine learning algorithms can be examined according to the evaluation table -in Fig. 2- including confusion matrix for classification algorithms, and the evaluation metrics [7].

<table>
<thead>
<tr>
<th>No</th>
<th>Class</th>
<th>Explanation</th>
<th>Training</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Attack</td>
<td>worm, virus</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>2</td>
<td>P2p</td>
<td>bittorrent,</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>3</td>
<td>Mail</td>
<td>pop3, smtp</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>4</td>
<td>Wwww</td>
<td>http, https</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>5</td>
<td>Services</td>
<td>dns, smtp</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>6</td>
<td>Bulk</td>
<td>ftp, ssh</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>7</td>
<td>Database</td>
<td>mysql,</td>
<td>1000</td>
<td>750</td>
</tr>
</tbody>
</table>

**TABLE III**

**KERNEL RADIAL BASIS FUNCTION**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>74.57</td>
</tr>
<tr>
<td>10</td>
<td>79.06</td>
</tr>
<tr>
<td>1</td>
<td>88.55</td>
</tr>
<tr>
<td>0.1</td>
<td>92.38</td>
</tr>
<tr>
<td>0.01</td>
<td>95.10</td>
</tr>
<tr>
<td>0.001</td>
<td>96.27</td>
</tr>
</tbody>
</table>

**TABLE IV**

**KERNEL POLYNOMIAL FUNCTION**

<table>
<thead>
<tr>
<th>Parameter1</th>
<th>Parameter2</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>75.14</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>64.88</td>
</tr>
<tr>
<td>0.01</td>
<td>1</td>
<td>75.70</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>60.84</td>
</tr>
<tr>
<td>0.001</td>
<td>1</td>
<td>75.45</td>
</tr>
<tr>
<td>0.001</td>
<td>0.001</td>
<td>92.69</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>18.63</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>21.14</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>93.07</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>26.06</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>21.31</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

The classification of data on the internet in order to make internet use more efficient has an important place especially for network administrators managing corporate networks. Studies for the classification of internet traffic have increased recently. Machine learning methods of classification of the internet traffic which is commonly used in our day and has been also selected for this study is the kernel based on extreme learning machine based approaches. In this study, over 95% was achieved accuracies using different activation functions. In this study, the kernel based ELM function; Radial Basis and Polynomial functions are used. Functions classification performance by changing the parameters used were observed. RBF is used for the first parameter value. Polynomial function for changing the classification is made and 2 parameter values. With a decrease of the parameter value used for RBF was found that the accuracy increases. This parameter value is 0.01 and reached a value of 95.10% accuracy. With 0.001 of these parameters have reached a value of 96.27% accuracy. But the increase has been observed that a lot of work time. 2 parameter value for Polynomial function is used. The value of 1 and 10 Accuracy rate of 93.07% was observed with the election.

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Hybrid Biometric System Using Iris and Speaker Recognition

Gökçen ÇETİNEL, LLukman ÇERKEZİ, Doğukan Uzuner, Barış Yazar

Abstract—In this study, a hybrid security system is proposed. The proposed system is composed of two subsystems namely iris recognition system (IRS) and speaker recognition system (SRS). Pre-processing, feature extraction and feature matching are the main steps of these systems.

In IRS subsystem, Gaussian filter, Canny edge detector, Hough transform, and histogram equalization is performed for pre-processing, respectively. After that, by applying 4-level Discrete Wavelet Transform (DWT) to pure iris image, the iris image is decomposed into four sub-bands (LL4, LH4, HL4 and HH4). In order to extract the feature vector from iris pattern, the LH4, HL4 and HH4 sub-bands (matrices) are merged into one matrix. Finally the matrix is transformed in vector to obtain the feature vector of iris image. For SRS subsystem, the pre-processing step includes spectral arrangement, silence part removing and band limitation operations. After pre-processing, frame blocking and windowing are applied to the long-term speech samples and then Fast Fourier Transform (FFT) is performed for the each short-term speech segments (frames). Finally, the Mel Frequency Cepstral Coefficients (MFCC) technique is performed in order to obtain feature vector of the speech.

The feature matching step of both IRS and SRS is implemented with Dynamic Time Warping (DTW) which is an efficient algorithm to measure the distance between two vectors. According to the DTW results, the false acceptance rate (FAR) is zero and false rejecting rate (FRR) is about 4% for the proposed hybrid system.

Keywords—Biometric systems, iris recognition, speaker recognition, DTW, security.

I. INTRODUCTION

Nowadays, with the emerging of information technology the security of digital data has gained a great importance. One way to protect the digital data from unauthorized persons is to use identification and access control mechanisms. In order to provide these mechanisms one emerging technology that becomes more widespread is biometrics.

Biometric systems are designed based on people’s physiological or behavioural characteristics. These systems can be defined as a pattern-recognition system which tries to recognize a person based on feature vector derived from her/his specific physiological or behavioural characteristics.

The physiological characteristics include fingerprint, face, iris, DNA, hand geometry whether the behavioural characteristics include gait, voice. Depending on application, a biometric system can operate for two main purposes: verification and identification. Verification refers the case where the user desires to be recognized by using an identity such as personal identification number (PIN), login name, smart card; and the system makes one-to-one comparison to determine whether this claim is true or not. The main goal is to prevent multiple people using the same identity. Identification refers the case where the system makes one-to-many comparison of user to determine who is exactly the user. The main goal is to prevent a single person from using multiple identities. One of the key advantages of biometrics over the traditional methods such as knowledge based systems is that biometrics cannot be lost or forgotten; they are difficult for attackers to forge and for user to repudiate [6].

Among biometric systems, iris recognition system is very popular due to significant reasons such as, uniqueness, non-invasiveness and high stability. Iris is part of human eye which lies between pupil and sclera. Iris cannot be copied so iris recognition system is the most reliable system in comparison with other biometric systems [2].

In recent years, speaker recognition also gained increased significance. Searching or controlling based on speaker identity is a growing interest in today’s technologies. Speaker recognition is commonly used in the applications of personal authentication, national security and general forensics. In this study, speech analysis and decision process is performed by computer analysis automatically. The main goal of the proposed speaker recognition system is to increase the security of entire hybrid system [5].

Speaker recognition consists of two main tasks: identification and verification. In speaker identification we intend to identify a speaker from a closed or open set of speakers. For speaker verification, the objective is to verify the claim of an unknown speaker is true or not. This verification is performed by comparing the speech samples of claimer and other speaker’s speech samples available in database. The characteristic of each speaker voice is typical and secret in her/his voice box. So, speaker recognition systems are the reliable biometric systems, too.

In this study, by connecting iris and speaker recognition systems in sequence, a hybrid high security biometric system is obtained. Both IRS and SRS are designed by applying pre-processing, feature extracting and feature matching (decision) steps. Used techniques in order to achieve these steps are explained in the corresponding sections. By performing computer simulations, it is shown that the proposed hybrid
biometric system (HBS) is more robust against to the intruders than separate biometric system. To evaluate the performance of the system FAR and FRR values are also calculated in the simulations. According to the results, we can say that the proposed systems ensure security requirements.

The paper is organized as follows. In Section II, IRS and SRS are explained with all steps, respectively. A brief information about used techniques in these steps are also given in Section II. HBS which consist of IRS and SRS is introduced in Section III. To evaluate the performance of the system, simulation results are given in Section IV. Finally, discussion and conclusion part is stated in Section V.

II. SUBSYSTEMS

In this section, two subsystems of the HBS are explained in details. Pre-processing, feature extraction and feature matching are the main phases of both subsystems.

A. Iris Recognition System (IRS)

Pre-processing: In pre-processing, eye image is transformed into an appropriate model to extract the distinctive features for recognition. Iris localization and normalization are two basic processes in pre-processing. In our study, before localization and normalization 2-D Gaussian filter is applied for noise reduction. Then, the edges are detected with Canny edge detector.

Iris localization is crucial for iris recognition systems. As we see, there are two contours in an eye. The first one is inner contour separating the iris and pupil; second one is the outer contour separating the iris and sclera. By using Circular Hough Transform (CHT), we obtain the inner and outer boundaries of iris. In other words, we estimate the centre and radius of contours.

Iris normalization is an operation converting iris region from Cartesian coordinates to polar coordinates. Thus, circular image turns into a rectangular form and now is suitable for feature extraction. As a last step, histogram equalization is used for enhancing the contrast of iris pattern. In Figure 1, pre-processing is illustrated.

Feature Extraction: In order to use iris signature for recognition systems, the representing of iris in an appropriate way is very important. To extract the specific features from iris, Discrete Wavelet Transform (DWT) is used. DWT is an efficient tool, which transforms the signal from time domain into frequency domain without losing time information.

In general, by performing DWT to 1-D signal, the original signal is divided in low and high frequency parts. This process is called as decomposition and it is provided through special analysis filters. The outputs of filter are referred as DWT coefficients and the original signal can be reconstructed from these coefficients by using appropriate synthesis filters (inverse DWT, IDWT). For 2-D signal case, after performing DWT, image will be divided into four sub-bands corresponding to low frequency (LL1), middle-frequency (LH1, HL1) and high frequency (HH1) components, respectively. DWT can be applied to the LL1 sub-band which concentrates the maximum energy of the signal, one more times until we get the desired level of decomposition. The middle and high frequency (LH1, HL1, and HH1) sub-bands represent the details of image such as edges, outline and texture.

In our study, we used 4-level DWT in order to extract the correct features from iris texture. By performing 4-level DWT we get LL4, LH4, HL4 and HH4 sub-bands. Since the distinctive features of iris are hidden in the high-frequency components, we constitute the feature matrix by merging LH4, HL4, and HH4 sub-bands in one matrix. Finally the matrix is transformed into a vector to obtain the feature vector of iris image.

B. Speaker Recognition System (SRS)

In SRS, at the beginning we record the speech of the users under same conditions. Since the SRS is text dependent recognition system, the users say the same words for database. The block diagram of the proposed SRS system is given in Figure 2. The steps of SRS can be explained as follows.

Pre-processing: In order to process a digital signal, first we must sample the analog signal by Nyquist frequency rate. Then, pre-processing step including spectral arrangement, silence part removing and band limitation operations is applied to the digitized signal.

For spectral arrangement, to enhance the high-frequency energy of the signal, we use a high-pass finite impulse response pre-emphasize filter. The transfer function of this filter is given as follows,

\[ H(z) = 1 - \mu z^{-1}, \quad 0.95 \leq \mu \leq 0.97 \]  

In silence part removing differentiation operation is performed on speech samples from left-to-right and right-to-
left to eliminate the non-variant (silence) parts. Then, in accordance with the human audio system, frequency components outside of 1KHz-5KHz band is stopped. This can be referred as band limitation.

**Feature extraction:** In general speaker recognition system, the critical step is feature extraction step. To achieve high recognition performance, it is known that the features should be extracted form short-time (20-25ms) speech segments. One of the most commonly used short-time features are Mel Frequency Cepstral Coefficients (MFCC). To calculate MFCC values, speech signals are divided into short overlapping frames. Then each frame is multiplied by a window function. In our study, we use Hamming window given as,

\[ w(n) = 0.56 - 0.46 \cos \left( \frac{2\pi n}{N-1} \right) \]  \hspace{1cm} (2)

where N is the length of the window. Then with Fast Fourier Transform (FFT), Fourier power spectrum is obtained. In the next step, the logarithm of the spectrum is calculated a Nonlinearly spaced triangular band

Frequency Cepstral Coefficients (MFCC). To calculate MFCC

we attain to MFCC.

The HBS is designed by connecting IRS and SRS subsystems as demonstrated in Figure 4. The HBS works as follows: at first the user tries to pass through IRS. If IRS denies his/her access, the system will automatically reject this attempt. On the other hand, if the user passes through IRS successfully, SRS is put into use. With the acceptance of SRS, the user will be able to enter.

**B. Feature Matching**

In this study, we use Dynamic Time Warping (DTW) technique to implement feature matching process. DTW is applied to feature vector which is constituted by combining iris image feature vector and MFCC. This technique is very efficient to find optimal distance between two vectors that may differ both in phase and length. The first step in algorithm is to determine local cost measure \( c(x, y) \) between each element of the X and Y vectors by calculating Manhattan distance. If \( c(x, y) \) is small, the similarity between X and Y is high and vice versa. In the second step, the cost matrix is obtained by evaluating the local cost for each pair of elements in X and Y feature vectors.

Algorithm tries to find a warping path \( p= (p_1, ..., p_u) \) which satisfies the following three conditions:

i) Boundary condition: \( p_1 = (1,1) \) and \( p_u = (N,M) \),

ii) Monotonicity condition: \( n_1 < n_2 < ... < n_u \) and \( m_1 < m_2 < ... < m_u \),

iii) Step size condition: \( p_{u+1} - p_u \in \{(1,0),(0,1),(1,1)\} \) for \( u \in [1:L-1] \)

The total cost \( c_p(X,Y) \) of a warping path between X and Y with respect to the local measure c is defined by

\[ c_p(X,Y) := \sum_{u=1}^{U} c(x_{n_u}, y_{m_u}) \]  \hspace{1cm} (3)

An optimal warping path between X and Y is a warping path \( p^* \) having minimal total cost among all possible warping paths. The DTW distance DTW(X,Y) between X and Y is then defined as total cost \( p^* \):

\[ \text{DTW}(X, Y) := c_{p^*}(X, Y) = \min \{ c_p(X, Y) \mid p \text{ is an } (N,M)\text{-warping path} \} \]  \hspace{1cm} (4)

DTW algorithm is widely used in speech processing applications due to the nature of speech waves. As far as we know, DTW algorithm is not applied for iris recognition systems. In our study, we used DTW both IRS and SRS and we obtained very promising results.
IV. EXPERIMENTAL RESULTS

In this section, the simulation results are given for IRS, SRS and HBS systems respectively. Simulations are performed by using MATLAB computer program. The performance of system is evaluated by calculating two rates defined as follows:

i) False Acceptance Rate (FAR): the probability of identifying an intruder as an enrolled user,

ii) False Rejection Rate (FRR): the probability of rejecting an enrolled user as if he was an intruder

Since the aim of HBS system is to ensure high security especially in a house, the database of our system is modelled for 10 people. For each user, 10 images of right iris and 10 sample voices are recorded. Two iris images and two sample voices are used for training among them. The iris images are provided by Casia Iris V4-Interval-R database. The size of iris images is 280x320. After applying pre-processing and feature extraction processes to the iris images we get a feature vector of size 1x84 for each image.

As discussed before, since our SRS sub-system is text dependent, the sentence “open the door” in Turkish is used as a password. The recording time is two seconds and the sampling frequency is 16kHz. After pre-processing and feature extraction we obtain a feature vector of size 1x40. Finally, we form feature vector for whole system by combining the feature vectors of IRS and SRS subsystems. The resulting vector’s size is 1x40.

After applying DTW algorithm to obtained feature vector we calculate the FAR and FRR values. These values are given in Table 1 for two subsystems and hybrid system. As can be seen from Table 1, the FAR values for these systems are zero. On the other hand FRR values are different in each system. By connecting IRS and SRS sub-systems we increase the security with HBS. A user must pass through both sub-systems in order to enter so it is almost impossible to cheat the system.

The FRR value of HBS is evaluated by using total probability theorem as given in the following equation

\[ \text{FRR(HBS)} = \text{FRR(IRS)} + \text{FRR}^C(\text{IRS}) \times \text{FRR(SRS)} | \text{IRS accepted} = 0.0125 + 0.9875 \times 0.025 = 0.037 \]  (5)

where FRR is false rejecting rate for HBS and \( \text{FRR}^C(\text{IRS}) \) is the probability of true decision in IRS.

It can be seen from Equation (5) that the FRR (HBS) value is smaller than FRR(SRS) value. Thus, by using HBS we can provide small FRR value and increase the robustness of system against fake biometric attack

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>FAR and FRR values for IRS, SRS and HBS systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FAR</td>
</tr>
<tr>
<td>IRS</td>
<td>0</td>
</tr>
<tr>
<td>SRS</td>
<td>0</td>
</tr>
<tr>
<td>SRS</td>
<td>IRS accepted</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In this study a novel Hybrid Biometric System (HBS) is proposed. First, the Iris Recognition System (IRS) and Speaker Recognition System (SRS) are designed and tested separately. The performances of sub-systems are evaluated by calculating FAR and FRR rates. Then, we connected two sub-systems to obtain the HBS system. The purpose of proposed HBS is to ensure high reliability. By means of the proposed HBS, to cheat system by spoof attacks is almost impossible.

ACKNOWLEDGMENT

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References
Mobile Application of Drug Follow-up Information System with Data Matrix Reader

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Abstract—The number of products that simplify people’s lives are increasing with the enormous development of the technology. Mobile devices have a great importance for the provision of communication which is one of the most significant need of human beings. Mobile devices have gone beyond to be used originally as a mobile phone purposes and they have begun to be used as smartphones by taking in charge of computers. They are not only used for communication but also they are used like camera, photo camera, notebook, television and reminder. Google’s Android platform is a widely anticipated open source operating system for mobile phones. Google’s Android Operating System (AOS) in mobile phones are still relatively new, however, AOS has been progressing quite rapidly. The increasing number of smartphone users has prepared the ground for the emergence of new ideas to make life easier. Recently, especially some applications in health sector reflect one of the most important samples for making life easier. Some of mobile applications in this field used by humans are about hearing test, vision test, diabetes, pregnancy, and doctor appointment. This paper focuses on following of drugs, taken by patients, through mobile phones. The application running on the AOS provides the use of drugs on time with the alarm system. In addition to this, the application gives information (time, dosage, name) about drugs by reading data matrix located on the medicine box. Thanks to visual and understandable interface and easy usage, many difficulties experienced in drug reception can be eliminated with this application. Finally, the percentage of reception of drugs on time can be increased in the future.

Keywords—Android, data matrix, web service, drug alarm, prospectus, smartphones, mobile programming.

I. INTRODUCTION

Providing access to health records with the communication networks and mobile devices from the desired location has been suggested as a growing business value in the health field[1]. The drug which is one of the most important thing in the field of health disorder is one of the most effective methods used for immunity. For this purpose, following of medicine becomes more difficult and it reveals a dangerous situation in terms of health for patients. All these problems have emerged the idea of mobile drug tracking application. The main purpose of drug tracking is to prevent disease by providing medicine taking in the right time.

Positive impacts of the market of mobile applications in the health sector are increasing day by day. Elderly population has led to increase the health expenditures in a remarkable way. Until 2030, health spending is expected to absorb %15 of the gross domestic product of developed countries. These countries such as Brazil, Russia, India and China anticipate that 175-200 billion dollars will be saved in the management of chronic diseases using mobile health applications actively. This means that the area of the mobile health will gain more importance in the future.

There are some systems for tracking up chronic illnesses developed by mobile operators such as “Türkcell Health Monitoring Service” and “Avea Patient Status Tracking System with Chronic illnesses” in Turkey.

In literature, there are numerous examples of mobile applications to make people’s life easier. Hacer and Kürşat[2] developed a web based mobile application of child tracking system. In their study, GPS (Global Positioning System) technology was used to provide location data. Another mobile application developed by Yuce et. al [3] focused on asthma, a chronic disease which can be control with patient-doctor cooperation involving frequent medical review and regular self-monitoring by basic indicators. In their study, they proposed to help patients keep their asthma under control and enable doctors reach patients. Finally, Kato and Tan[4] reviewed the six 2D barcodes and then use an extra metric - a first-read rate - to quantitatively verify our earlier results and better gauge reading reliability.

II. BARCODE AND DATA MATRIX TECHNOLOGIES AND STANDARDS

Barcode technology is one of the information coding standard. Barcodes are interface elements that provide access to encoded data via the optical reader. As seen Fig. 1, barcodes, consisting of vertical lines and spaces of different thicknesses, is a method used to transfer data automatically and error-free manner to another environment.

Fig. 1 Sample barcode labels
The use of barcode system has provided great advantages in daily life and business. This technology provides fast and accurate data reading. In addition to this, it provides time saving in the processes such as data update.

There are many types of barcode which have the serious areas and development process past to present. Generally, the basic characteristic that distinguish species from each other are the amount of information that the code can hold. Fig. 2 demonstrates the types of barcode used in literature.

In this paper, data matrix is preferred because of its use in the pharmaceutical industry. Some basic information about data matrix is given as follows:

**Fig. 2 Some barcode types[5]**

- **A. Data Matrix**

  Data matrix code is a two-dimensional matrix barcode consisting of black and white "cells" structured in either a square or rectangular pattern. Encoded information on the data matrix can be text or numeric. Data matrix which can save 3116 numerical or 2335 character can hold more data than one-dimensional barcode. On data matrix, while each black cell refers "1", each white cell refers "0" mathematically.

**III. SYSTEM ARCHITECTURE**

In this study; we proposed a system which consists of an application to be installed on the mobile device with Android operating system, a database where the drug information is stored, and a Windows Communication Foundation (WCF) service which provides the data exchange between them.

- **A. Database**

  SQL Server Express is a database system, developed and distributed by Microsoft, which can be used to provide a basis for the applications running on desktop and small servers. Microsoft's Azure cloud infrastructure and application platform, provide easy way of moving SQL Server databases to Azure. The database is designed to be moved to cloud in the future. SQL Server serves the majority of the database and management tasks. Because of such facilities SQL Server has been the preferred database server for our application.

- **B. WCF Service**

  The main objective of WCF is to enable the communication between applications on the network or internet. Representational State Transfer (REST) is an architecture to provide the data transfer between client and server via Hyper-Text Transfer Protocol (HTTP). Since REST services are Platform-independent, language-independent an easy to scale, REST architecture is preferred in our system. The return types of REST Services can be used as Extensible Mark-up Language (XML), JavaScript Object Notation (JSON), etc. based on the need. JSON is preferred in our application because it can transfer smaller pieces of information while transferring data in the application, and it is easier to use on the mobile platforms. As an example, the barcode number and drug information which is sent to the service is illustrated in Fig. 3 in JSON format. Likewise the database system, the service is also designed to be moved to the cloud.

**Fig. 3 JSON Format**

- **C. Mobil Application of System**

  For the mobile application, the open source operating system, Android, is used, and Android Studio is preferred as an editor. The purpose of this mobile application is to let the users doing medication tracking via Android mobile devices. One of the most important features of the application is to notify the user when it is medication time and to let the medication is taken on time. The medication alarm can be set manually as well as via...
the QR code on the drug. In addition to this, multiple alarms can be set.

The QR code on the drug was created to enable drug tracking. The QR code consists of the barcode number for the drug (GTIN: Global Trade Item Number) and a Serial Number (SN). By integrating the Batch Number (BN) and the Expiration Date (XD) to this unified record system, the obtained information is written on the drug.

In this mobile application, information about drugs can be gathered not only by their names but also by their barcode number. For this solution, application needs a barcode scanner. There is a library for barcode scanning on mobile devices called Zebra Crossing (ZXing). In order to read the QR code, ZXing library is used. ZXing is an open source, multi-format 1D/2D barcode image processing library implemented in Java. This library enables users to scan and read the QR code on the drug, utilizing the camera on the mobile devices.

On the opening screen of the mobile application, the list of tracked medications takes place, as shown in Fig. 4. To add a new record to this list, we open the record screen in Fig. 5, via the “Plus” button. In this screen, a drug reminder can be set through entering the activeness, title, hour, repeating days of the medication reminder, the ring tone, and whether the vibration is on or off, or by reading the QR code in Fig. 6, and clicking the “SAVE” icon. After this stage, the application is redirected to the screen in Fig. 4.

In case the of drug is wanted to be deleted or the drug information is wanted to be updated, the deletion or update can be accomplished by selecting the item from the list in the opening screen and using the screen in Fig. 5. In order to delete the record easily, the item is pressed and hold for a while in the opening screen.
Either by clicking the “DRUG” icon on the opening screen or through the QR code reading screen shown in Fig. 6, the information about the drug can be seen as demonstrated in Fig. 7.

![Drug Information Screen](image)

**Fig. 7 Drug Information Screen**

**IV. CONCLUSION**

With the increased use of mobile devices, mobile applications have made a quick entry into our lives in many areas such as education and health. Health applications attract the interest of both health workers and patients.

In this application that users can use on smart phones and tablet computers, follow the prescription section, taking drugs time and amount of dosage reminders for informative system. Application makes possible to add up to the required medication reminder record. The reminder of each drug is shown separately and when desired a reminder notification can be added for each drug. The most important benefit of this application is that nearly almost problems about drug intake (dosage, time interval …etc.) will disappear. As a result, receiving time of the overall drug percentage will be raised by this application.

**REFERENCES**


A Hybrid Algorithm for Automated Guided Vehicle Routing Problem

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Abstract— Nowadays, automatic systems become a crucial in many factories to achieve some tasks such as minimizing cost, maximizing efficiency, quality, and reliability. The planning is important for manufacturing systems to adopt changing conditions. Also, manufacturers want to obtain fast, reliable, qualified and economic products. Flexible Manufacturing Systems (FMSs) are used to meet this need. FMSs make production fast, qualified, reliable and economic by using computer-controlled structure that includes robots and transportation systems. Automated Guided Vehicles (AGVs) and FMS are thought to be integrated because FMS uses AGV as a part of transportation in the factory. AGVs are used to carry loads, in other words products, in production areas, warehouses, factories that use magnets, landmarks, laser sensors, lines to know where they are. AGV scheduling and routing is NP-hard and open-ended problems. In the literature, there are many algorithms and methods are proposed to solve these problems. In this study, we present a hybrid algorithm that is composed of simulated annealing (SA) and Dijkstra’s algorithm to solve the routing problem. The hybrid algorithm is compared with SA algorithm in terms of distance cost using benchmark problems in the literature.


I. INTRODUCTION

Nowadays, there are many factories that use automated systems to improve quality while minimizing cost to meet demands of customers in competitive market. There can be uncertainties and changes due to this competition. The result of these uncertainties and changes is decreasing performance and flexibility. Therefore, routing and scheduling is important to prevent such an undesired condition. Flexible Manufacturing Systems are used to meet this need. FMSs make production fast, reliable, qualified and economic by using computer-controlled structure that includes robots and transportation systems. Coordination in FMS is important for production and transportation because it is required to schedule limited resources in industry. If FMSs are well-planned, coming jobs are done on time. Therefore, production and transportation is carried out smoothly. AGVs are indispensable parts of FMSs. Here, AGVs are responsible for transportation in FMSs.

AGV control includes duty assignment, routing and scheduling [1]. AGV routing and scheduling can be done either online or offline. While offline planning requires prior knowledge related to tasks (it can be nodes, duties and so on), online planning enable to give new tasks [2].

Actually, AGV scheduling and routing problems are very complex in reality. However, this problem will be solved in this paper by simplifying and ignoring some conditions. Details related conditions, assumptions and constraints will be given in following parts.

The paper is organized as the follows. Related works in literature for AGV routing is given in section 2. Section 3 focuses on problem statement, in other words, assumptions, constraints and information about used algorithms. Test results for proposed algorithm are given in section 4. Finally, conclusion part summarizes all written things in the paper with short paragraph in section 5.

II. LITERATURE REVIEW

As mentioned before, scheduling and routing of AGVs is NP-hard problem. Therefore, there are so many researches and solutions in literature and also researchers have been still trying to deal with it. There are so many methods to solve AGV or vehicle routing problem such as simulated annealing algorithm, genetic algorithm, tabu search and so on. Also, some hybrid algorithms that are composed of two or more algorithms are available in the literature.

Liu and Fu [3] dynamically solve the vehicle routing, scheduling and planning problem by using A* algorithm, minimax criterion and some heuristic rules. They model the problem as optimal routing assignment of ‘p’ AGVs among ‘m’ workstations in order to accomplish ‘n’ tasks by using AGV in FMS. Czech and Czarnas [4] investigate the vehicle routing problem with time windows. Parallel-simulated annealing algorithm is proposed to solve routing problem assuming that there is a central depot of cargo and customers a particular distance far away from the depot. The effectiveness of the method is tested on some well-known instances of the problem. Lin et al. [5] apply an algorithm combining simulated annealing with local search approach to handle capacitated vehicle routing problem (CVRP) and test the algorithm on fourteen benchmark problems having different settings. Onoyama et al. [6] propose an algorithm to solve vehicle routing problem for a cooperative logistics network by using genetic algorithm. They use multistage GA and a method of multistage point evaluation to satisfy the
optimization of a cooperative logistics network. Here, they claim that the method of multistage GA gives a chance to obtain accurate solution under various conditions. The paper of Morhiro et al. [7] is about an online ‘Tasks Assignment and Routing Problem’ as called TARP. Their method is for an initial task assignment of autonomous distributed vehicle systems that uses finite buffer capacity. Also, the purpose of the method is to decrease the computation time of route planning by using initial task assignment. In other words, the importance of selecting initial task in a right way is emphasized. Wu and Zhou [8] propose an algorithm to find shortest time routes by controlling deadlock and blocking in AGV systems because they are undesired. Bouhafs et al. [9] propose a hybrid algorithm that uses tabu search and ant colony algorithm to solve ‘Capacitated Location-Routing Problem’ that is composed of ‘Facility Location Problem’ and ‘Vehicle Routing Problem’. The purpose of using tabu search is to find distribution centers with reasonable configuration. Also, the purpose of using ant colony algorithm is finding a route for configuration founding in tabu search step. Another tabu search method is proposed by Guan and Shi [10] for vehicle routing problem. They suggest that their approach is more intuitive and easy to understand client-direct-arrangement solution method coded with C language. Li et al. [11] improve the tabu search for the vehicle routing with fuzzy demands. The purpose is to minimize total distance. Traditional tabu search is compared with the proposed improved tabu search to see the effectiveness of the algorithm.

In this work, SA algorithm is combined with Dijkstra’s algorithm to improve the performance of SA algorithm. Then, SA and hybrid SA are compared in a table to show effectiveness of new algorithm. Details of the algorithm are given in the following parts.

III. IMPLEMENTED ALGORITHM

Implemented hybrid algorithm consists of both SA and Dijkstra. SA gives a route for each AGV and Dijkstra enhance the routes by shortening them. So, performance of the SA algorithm is increased by Dijkstra.

Before the implementation of algorithm, assumptions and constraints should be determined because of ease of coding.

Assumptions and constraints are given as the following:

- All nodes are connected with each other.
- There is one depot and more than one distribution center.
- All AGVs are capacitated and total demand must be smaller than or equal to the total capacity of AGVs.
- Collision between AGVs does not take into account, or in other words, there is a sufficient gap for passing through more than one AGV at the same time.

After the assumptions and constraints, giving information about SA and Dijkstra’s algorithm can be useful to understand hybrid algorithm.

A. Simulated Annealing Algorithm

Simulated annealing algorithm is a metaheuristic method that is used to find maximum or minimum of a function without trapping local maxima or minima. Algorithm starts with an initial solution and tries to find better solution by randomly changing some neighbors. However, some high-cost solutions are selected if the probability of it is greater than a probabilistic value [12].

Actually, this method can be associated with cooling process of metal. In thermodynamics, metals should be cooled carefully and slowly. When the metals are abruptly cooled, they will have fragile structure that is undesired. At the same way, if there are abrupt changes in simulated annealing algorithm, it may trap local values. Therefore, small changes are preferred for both.

Simulated annealing method is used in electronic circuit design, image processing, path finding problem, travelling salesman problems, scheduling problems [13]. In this paper, SA is used for routing of AGVs.

B. Dijkstra’s Algorithm

Dijkstra’s algorithm is used to find shortest path between nodes in a graph by using open list and closed list logic proposed by Edsger W. Dijkstra in 1956 [14]. In this paper, Dijkstra’s algorithm is used to make the distance found by SA shorter.

Pseudo codes of SA and hybrid SA are given in algorithm 1 and algorithm 2, respectively to show the difference between them.

Algorithm 1: Simulated Annealing Algorithm

1. Generate an Initial solution, S
2. Select a value for initial temperature, T
3. Select a value for minimum temperature, T_{min}
4. while (T < T_{min})
   - Generate a neighborhood solution S’ of S
   - Δ=DistanceCost(S)’ -- DistanceCost(S)
   - If Δ<0, S=S’
     - Generate a number r between 0 and 1.
   - End if
   - If Δ>0, S=S’ with exp (-Δ/T) > r
     - T=α*T
   - End if
5. end while

Initial solution in (1) of Algorithm 1 is found using nearest neighbor strategy. Each service node is firstly ordered minimum to maximum according to distance to depot. Then, each service node is assigned to each AGV respectively. This step continues until no service node is left.

Algorithm 2: Hybrid Simulated Annealing Algorithm

1. Generate an Initial solution, S
2. Select a value for initial temperature, T
3. Select a value for minimum temperature, T_{min}
The “DijkstraOrder” function is applied each route of AGV in neighborhood solution $S'$. This function is ordered the route of each vehicle considering the shortest path cost.

**IV. EXPERIMENTAL RESULTS**

The algorithms are coded in C#. The tests for hybrid algorithm are done on a laptop with Windows 7, Intel Core i7 CPU and 8 GB Ram.

Simulated Annealing (SA) and hybrid SA algorithms are compared in terms of best distance costs using problem set by Augerat et al [15]. The instances range from 32 to 80 service nodes. Number of AGVs is changed from 5 to 10 according to problem set. In addition, the capacity of each vehicle for all problem set is 100. The problem set description and best distance cost results obtained using SA and hybrid SA are given in Table I.

**TABLE I**

<table>
<thead>
<tr>
<th>Problem Set Name</th>
<th>Number of Service Nodes</th>
<th>Number of AGV</th>
<th>Capacity</th>
<th>Best Cost with SA</th>
<th>Best Cost with Hybrid SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>32</td>
<td>5</td>
<td>100</td>
<td>808.55</td>
<td>803.66</td>
</tr>
<tr>
<td>A2</td>
<td>33</td>
<td>3</td>
<td>100</td>
<td>662.00</td>
<td>675.70</td>
</tr>
<tr>
<td>A3</td>
<td>33</td>
<td>6</td>
<td>100</td>
<td>746.80</td>
<td>743.44</td>
</tr>
<tr>
<td>A4</td>
<td>34</td>
<td>5</td>
<td>100</td>
<td>788.72</td>
<td>791.86</td>
</tr>
<tr>
<td>A5</td>
<td>36</td>
<td>5</td>
<td>100</td>
<td>831.32</td>
<td>835.09</td>
</tr>
<tr>
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<td>37</td>
<td>5</td>
<td>100</td>
<td>694.91</td>
<td>694.26</td>
</tr>
<tr>
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<td>6</td>
<td>100</td>
<td>990.06</td>
<td>979.92</td>
</tr>
<tr>
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<tr>
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<td>5</td>
<td>100</td>
<td>854.89</td>
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<tr>
<td>A10</td>
<td>39</td>
<td>6</td>
<td>100</td>
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<td>6</td>
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<td>100</td>
<td>1387.27</td>
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<tr>
<td>A22</td>
<td>63</td>
<td>10</td>
<td>100</td>
<td>1736.10</td>
<td>1717.60</td>
</tr>
</tbody>
</table>

Some parameter settings are required to run simulated annealing algorithm and values of them are crucial. Parameters, expressions and corresponding values are given in Table 2.

**TABLE 2**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Expression</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T$</td>
<td>temperature</td>
<td>100</td>
</tr>
<tr>
<td>$T_{\text{min}}$</td>
<td>Minimum temperature</td>
<td>1</td>
</tr>
<tr>
<td>$r$</td>
<td>Annealing ratio</td>
<td>0.2</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Cooling parameter</td>
<td>0.9999</td>
</tr>
</tbody>
</table>

As seen in Table 1, hybrid SA gives better results except for three of 27 results in terms of distance. Visualization of first data set A1 is made with simulated annealing in Fig. 1 and with hybrid simulated annealing in Fig. 2 for better understanding.
This page contains a discussion on the application of autonomous AGVs in transportation and the evaluation of different algorithms for their routing. The text also refers to the use of Simulated Annealing (SA) and its effectiveness compared to other methods. The figures illustrate the routes of AGVs, showing how SA can be used to optimize these routes. The references section cites various studies on AGV systems, including those on Simulated Annealing and other optimization techniques.

**Fig. 1** gives the route of the AGVs as the following:

Route for AGV 1: 1-21-6-26-11-16-23-10-9-19-30-1
Route for AGV 2: 1-28-25-1
Route for AGV 3: 1-15-29-12-5-24-3-4-7-27-1
Route for AGV 4: 1-8-14-18-20-32-22-1
Route for AGV 5: 1-31-17-2-13-1

**Fig. 2** gives the route of the AGVs as follows:

Route for AGV 1: 1-21-6-26-11-16-10-23-30-1
Route for AGV 2: 1-28-25-1
Route for AGV 3: 1-19-9-12-5-29-24-3-4-27-1
Route for AGV 4: 1-15-7-18-20-32-22-14-1
Route for AGV 5: 1-31-17-8-2-13-1

As seen above, routes for AGVs are generally different in Fig. 1 and Fig. 2 but it is not important because algorithm is probabilistic and can give different results at each run. It is required to control whether total distance is getting smaller or not. Distance can be controlled with Table I and it can be said that SA is improved by using Dijkstra’s algorithm.

**V. CONCLUSION**

So many factories use automatic systems due to developing technology to minimize cost and maximize efficiency, quality, and reliability. FMSs are used to meet this need. AGVs play a big role in this for the duty of transportation. It is required to make route planning of AGVs to use them effectively due to costs. SA algorithm is the one of the common methods in literature to solve the routing problem of AGVs. In this study, it is combined with Dijkstra’s algorithm that is another common method in literature. Hybrid algorithm is tried on problem set by Augerat et al as mentioned before. Obtained results show that the hybrid approach gives better distance results. In the future work, the algorithms are planned to handle the problem for the autonomous AGVs.

**REFERENCES**


The Use of Intelligent Water Drops (IWD) for B-Spline Curve Fitting

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Abstract— The use of B-spline curves has spreaded too many fields such as computer aided design (CAD), data visualization, surface modeling, signal processing and statistics. The flexible and powerful mathematical properties of B-spline are the cause of being one of the most preferred curve in literature. They can represent a large variety of shapes efficiently. The curve behind of the model can be obtained by doing approximation of control points, approximation of knot points or parameterization. It is obvious that the selection of knot points in B-spline curve approximation has an important and considerable effect on the behavior of final approximation. In addition to this, an unreasonable knot vector may introduce unpredictable and unacceptable shape. Recently, in literature, there has been a considerable attention on the algorithms inspired from natural processes or events to solve optimization problems such as simulated annealing, ant colony optimization, particle swarm optimization, artificial bee colony optimization, and genetic algorithms. This paper implements and analyzes a solution to approximate B-spline curves using Intelligent Water Drops (IWD) algorithm. This algorithm is a swarm based optimization algorithm inspired from the processes that happen in the natural river systems. The algorithm is based on the actions and reactions that take place between water drops in the river and the changes that happen in the environment that the river is flowing. Some basic properties of natural water drops are adopted in the algorithm here to solve B-spline curve fitting problem. Optimal knots are selected through IWD algorithm. The IWD algorithm was experimented by some benchmark functions. The proposed algorithm convergences optimal solutions and finds good and promising results.

Keywords— Intelligent water drops, natural water drops, evolutionary algorithms, B-Spline curves, knot points, optimization, reverse engineering.

I. INTRODUCTION

B-spline curves are usually used in computer aided design (CAD), data visualization, surface modeling and many other fields. B-spline curve data fitting is a challenging problem encountered in reverse engineering. However, B-spline curves are most preferred approximation curve because they are very flexible and have powerful mathematical characteristics. Because of this feature, they can offer a large variety of shapes efficiently. In literature, many approaches and methods have been developed for B-spline curve approximation. Tirandaz et al.[1] studied on curve matching and character recognition using B-spline curves. In this work, dominant points on the borders of the object calculated by Local Curvature Maximum (LCM) and control points are calculated by least square method. Consequently, similar characters are determined by utilizing data set of sample characters. Valenzuela and Pasadas[2] used simulated annealing method for cubic spline approximation for knot adjustment. Discrete curvature of data points was smoothed by low pass filters. Artificial immune system is used for optimization of the knots. Gálvez and Iglesia[3] calculated positions of the optimal knots using particle swarm optimization algorithm which was one of the most important metaheuristic approach in literature. They highlighted that parameters of the algorithm had an significant effect on the performance of the curve fitting problem. Finally, Gálvez et al.[4] studied elitist clonal selection algorithm for selecting optimal free knots. In their study, the focused on artificial immune system for the problem of knot adjustment. They mentioned that adjustment of computation time and parameters were basic limitation of the method but it was a matter of tuning parameters based on metaheuristic technical problems and they emphasized that this problem was inevitable. Standart problems solved by IWD algorithm are well known in literature such as vehicle routing problem, travelling salesman problem and robot routing problem. Differently, Dadaneh et.al[5] applied IWD algorithm to tackle the graph coloring problem.

This study focuses on the swarm based IWD algorithm which is inspired from natural colonizing behaviour of water drops in nature. Optimal knot points for drawing the curve are determined by applying proposed algorithm. We demonstrated the effectiveness of the proposed method using numerical studies on multiple representative functions.

II. B-SPLINE CURVES

B-spline curves can be determined for a collection of \( n + 1 \) control points. The first and the last control points intersect with curve. The degree of the curve is \( d \) and must be satisfy the equation \( 1 \leq d \leq n \). B-spline curves use blending functions which have local domain areas to overcome restrictions and disadvantages. These functions are equal to zero outside of own
parts. The mathematical definition of the B-spline curve is formulated as follows:

\[ P = \sum_{i=0}^{n} (p_i N_{i,d}) \]  

(1)

where \( p \) is the control points, \( d \) is the curve degree, \( n + 1 \) is the number of control points and \( N_{i,d} \) is the blending function which is calculated as follows:

\[ N_{i,d}(u) = \begin{cases} 
1, & t_i \leq u \leq t_{i+1} \\
0, & \text{otherwise} 
\end{cases} \]  

(2)

\[ N_{i,k}(u) = \frac{u-t_i}{t_{i+k}-t_i} N_{i,k-1}(u) + \frac{t_{i+k+1}-u}{t_{i+k+1}-t_i} N_{i+1,k-1}(u) \]  

(3)

where \( t \) is the elements of knot vector. The main framework of the B-Spline curve drawing is demonstrated as follows[6]:

1. When a point cloud \( (p_i, i = 0, ..., M_u) \) is given, some points \( Q_j, i = 0, ..., m \) and \( n \leq M_u \) are selected and Centripetal knots are calculated with these points. Here \( u \) shows each Centripetal knot:

\[ u_0 = 0 \quad u_m = 1 \]  

(4)

\[ u_i = u_{i-1} + \frac{\sqrt{Q_i - Q_{i-1}}}{\sum_{j=0}^{m} \sqrt{Q_j - Q_{j-1}}} \]  

(5)

\[ Q_i - Q_{i-1} = (x_i - x_{i-1})^2 + (y_i - y_{i-1})^2 \]  

(6)

2. Approximate B-Spline knots can be found by using calculated Centripetal knots. At this step, the following equation is used:

\[ U = [0, 0, ..., 0, u_{d+1}, ..., u_m, 1, 1, ..., 1] \]  

(7)

\[ u_{j+d} = \frac{1}{d} \sum_{i=j}^{j+d-1} u_i, \quad j = 1, ..., m - d \]  

(8)

3. Control points can be obtained by using the equation \( Q = P \times R \) which is the B-spline curve formula. In this equivalence, in order to obtain \( P \) (control points) matrix, at first, \( R \) matrix should be obtained by using blending functions. Matrix operations are applied over the equation \( Q = P \times R \) to left \( P \) alone. Accordingly, \( P \) is calculated using the equation \( P = Q \times R^{-1} \)

4. As a result, B-spline curve can be drawn.

5. The error value is calculated by using data estimated and data obtained. This approach is called Euclidean error sum which is expressed as follows:

\[ Error = \sum_{i=1}^{n} |S_i - F_i|^2 \]  

(10)

III. INTELLIGENT WATER DROPS

IWD is a swarm based numerical optimization algorithm inspired from natural colonizing behaviour of natural water drops in river. This algorithm contains a few essential elements of natural water drops and actions and reactions that occur between river's bed and the water drops that flow within. This IWD has two important attributes:

- The amount of soil it carries now, \( soil^{IWD} \)
- The velocity that it is moving now, \( vel^{IWD} \)

The values of the both properties may change as the IWD flows in its environment. This environment depends on the problem at hand. The goal of the problem is to find the best path from the source to the destination. One of the most important mechanism that exists in the behavior of an IWD is that it prefers the path with low soils on its bed. In this point, the probability of the next path to choose inversely proportional to the soils of the available paths. As a result; the lower the soil of the path, the more chance it has for being selected by the IWD. In the following, we will discuss the algorithm rules in details.

Path selecting rule: For each IWD, the probability \( p(i, j; IWD) \) of the choosing next location is given by Eqs. 11, 12 and 13 respectively[7]:

\[ p(i, j; IWD) = \frac{f(soil(i, j))}{\sum_{k\in\text{vic(IWD)}} f(soil(i, k))} \]  

(11)

\[ f(soil(i, j)) = \frac{1}{\epsilon_s + g(soil(i, j))} \]  

(12)

\[ g(soil(i, j)) = \begin{cases} 
soil(i, j) & \text{if } \min_{l}(soil(i,l)) \geq 0 \\
\epsilon_s - \min_{l}(soil(i,l)) & \text{else} 
\end{cases} \]  

(13)

where the set \( \text{vic(IWD)} \) represents the locations that the IWD should not visit to keep satisfied the constraints of the problem, \( \epsilon_s \) is a small positive number to prevent possible zero division,
the function \( \min(\cdot) \) returns the minimum value of its arguments.

**Velocity updating rule:** For each IWD that moves from current location \( i \) to next location \( j \), the velocity of IWD is updated as follows\[7\]:

\[
vel^{IWD}(t + 1) = vel^{IWD}(t) + \frac{a_v}{b_v + c_v \cdot soil(i,j)}
\]  

(14)

where \( vel^{IWD}(t + 1) \) shows the updated velocity of an IWD at the location \( j \), \( soil(i,j) \) is the soil on the path joining the current location \( i \) and the next location \( j \), \( a_v, b_v \) and \( c_v \) are constant velocity parameters.

**Local soil updating rule:** For each IWDs moving, the amount of soil \( (soil(i,j)) \) and the soil that each IWD carries \( (soil^{IWD}) \) are updated with the Eqs. 15, 16, 17 and 18 respectively\[7\]:

\[
soil(i,j) = (1 - \rho) \cdot soil(i,j) - \rho \cdot \Delta soil(i,j)
\]  

(15)

\[
soil^{IWD} = soil^{IWD} + \Delta soil(i,j)
\]  

(16)

\[
\Delta soil(i,j) = \frac{a_s}{b_s + c_s \cdot time(i,j; vel^{IWD})}
\]  

(17)

\[
time(i,j; vel^{IWD}) = \frac{||c(i) - c(j)||}{\max(e_v, vel^{IWD})}
\]  

(18)

where \( \Delta soil(i,j) \) is the soil which \( vel^{IWD} \) removes from the path between \( i \) and \( j \) and \( \rho \) is a small positive number generated from the interval \([0,1]\). In addition \( a_v, b_v \) and \( c_v \) are constant soil parameters and \( e_v \) is a small positive number to prevent possible zero division (According to original algorithm for finding the best tour we calculate the path with minimum length, however sometimes depending on the problem different measures can be used. For this study, we use error value between original curve and fitted curve instead of Euclidean error.)

**Global soil updating rule:** At the end of the each iteration, the amount of soil on the edges of the best tour (solution) \( (T_B) \) is updated via Eq. 19\[7\]:

\[
soil(i,j) = (1 - \rho) \cdot soil(i,j) + \rho \frac{2 \cdot soil^{IWD}}{N_c(N_c - 1)} \quad \forall (i,j) \in T_B
\]  

(19)

where \( N_c \) is the number of city that IWD visits on its path. According to obtained best solutions, total best solution is updated.

Taking into account four key rules described above, the steps of implementing standard IWD algorithm can be summarized as follows\[7\]:

1. The initialization of static parameter values.
   a. Representation of the problem in a graph format.
   b. Setting values for static parameters.

2. The initialization of dynamic parameter values.
3. Distribution of IWDs on the problem’s graph.
4. Updating the list of visited cities for each IWD.
5. Following of steps a-d for partial solutions:
   a. Selecting the next city for each IWDs.
   b. Velocity updating of each the IWD which moves from location \( i \) to \( j \).
   c. Calculation of soil.
   d. Updating of soil.

6. Finding the best of the solutions obtained by IWDs in the respective iteration.
7. Updating of soil amount of the edges which is on the best solution.
8. Updating of best solution.
9. Increasing the number of iteration.
10. Returning the best solution when the termination criterion is satisfied.

There are some improved versions of IWD method in literature. These adaptive IWD, improved IWD, modified IWD and neural IWD are examples.

**IV. B-SPLINE CURVE FITTING WITH IWD**

This paper focuses on the problem of selecting optimal knots for the best B-spline curve fitting. Data points have been accepted as a cities and all water drops start from the same point. When a water drop reaches predetermined point, it is accepted that this water drop completed its tour. At the end of the algorithm, the cities on the best path are accepted optimal points to fit data. Fig. 2 shows the optimal data points for the B-spline curve fitting.

In this study, some modifications have been made on the IWD method. The selection of some unnecessary points has been prevented by adding the concept of the radius of curvature. Neighborhood-based local search increases the probability of selecting better ways. Another concept that has been added to the steps of the algorithm is the diversity rate used in local search step. In this way, paths that water drops may follow are gone up. Experimental studies demonstrate that diversity rate prevents hanging out the local minimum. In the following section, some experimental studies were represented to demonstrate the effectiveness of the proposed algorithm.
V. EXPERIMENTAL STUDIES

In this section, numerous numerical simulations are performed to demonstrate the effectiveness of the proposed optimization algorithm. The scope of B-spline curve fitting, IWD algorithm is coded. On the knot prediction of curve in question, mentioned reverse engineering approaches and optimization process steps have been combined. Some parameters and values used in the problem are given in the following table:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of knot</td>
<td>&gt; 6</td>
</tr>
<tr>
<td>Curve degree</td>
<td>3</td>
</tr>
<tr>
<td>Number of iteration</td>
<td>&lt; 20</td>
</tr>
<tr>
<td>Number of IWD</td>
<td>[3,10]^*</td>
</tr>
<tr>
<td>Tolerance error</td>
<td>0.0001</td>
</tr>
<tr>
<td>The number of neighbors</td>
<td>[1,10]^*</td>
</tr>
<tr>
<td>Diversity rate</td>
<td>[10,100]^*</td>
</tr>
</tbody>
</table>

Table 1: Algorithm parameters (*all values in the range used in simulations)

Static parameter values used in the proposed algorithm for the solution of B-spline curve fitting problem are listed as follows:

Table 2: Static parameters of the proposed algorithm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a_s)</td>
<td>1000</td>
</tr>
<tr>
<td>(b_s)</td>
<td>0.01</td>
</tr>
<tr>
<td>(c_s)</td>
<td>1</td>
</tr>
<tr>
<td>(a_v)</td>
<td>1000</td>
</tr>
<tr>
<td>(b_v)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Table 3 shows their corresponding mathematical definitions and associated domains. Each function is evaluated at uniformly distributed values of \(t\) in its domain to generate a collection of 201 data points on the interval [0,1].

Table 2: Static parameters of the proposed algorithm

\[
SE = \sum_{k=1}^{N} (y_k - F(x_k))^2 \quad (22)
\]

where \(N\) is the number of data used in the approximation by cubic spline, \(N_{od}\) is the number of interior knots used for construction of B-spline, \(m\) is the order of the spline to be fitted for the given data, and \(SE\) is sum of squared error.

The reason why we used AIC and BIC as a fitness function is that they do not use subjective parameters such as error limits and smoothing functions. Therefore, these functions provide simple and straightforward procedure for identifying the best result[3]. According to these functions, lower values denote better fitness values.

Proposed method is compared with the elitist clonal selection algorithm. In that study, Galvez et. al[4] introduced an adopted elitist clonal selection algorithm for automatic knot adjustment of B-spline curves. In their study artificial immune system paradigm was applied to solve knot adjustment problem for B-spline curves. In this section, performance of the methods was compared by calculating AIC and BIC.

Our algorithm for B-spline curve fitting has been applied to several test functions and we consider here three of them, displayed in Fig. 1.

Table 3: Test functions used in this paper: mathematical definition[3]

<table>
<thead>
<tr>
<th>Equation</th>
<th>Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>(f_1(t) = \frac{1}{1 + e^{-10(t-0.6)}})</td>
<td>(0 \leq t &lt; 0.6)</td>
</tr>
<tr>
<td>(f_2(t) = \begin{cases} \frac{1}{2} &amp; \text{if } 0.015 + (t - 0.65)^2 \ \frac{1}{8} &amp; \text{if } 0.015 + (t - 0.3)^2 \ \frac{1}{2} &amp; \text{if } -1 \leq t \leq 1 \end{cases})</td>
<td>(0.6 \leq t \leq 1)</td>
</tr>
<tr>
<td>(f_3(t) = \frac{100}{1 + e^{-10(0.4 - t)^2}})</td>
<td>(0 \leq t \leq 0.1)</td>
</tr>
</tbody>
</table>

All experiments in this paper have been performed on a 2.4 GHz, Intel Core i7 processor with 12 GB. Of RAM. The source code has been implemented by the authors in the programming language of the popular scientific program Matlab, version R2015a. The reason for selection of Matlab is that it is very fast, and it provides reliable, well tested routines for efficient matrix manipulations.

For this study we compute two fitness functions: Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC). AIC and BIC which are used to measure performance are defined as follows:

\[
AIC = N \log{SE} + 2(2N_{od} + m) \quad (20)
\]

\[
BIC = N \log{SE} + \log{N}(2N_{od} + m) \quad (21)
\]
Fig. 2 Selected data points of functions $f_1$, $f_2$ and $f_3$, respectively. The red dots represent data points (true function); blue circles represent selected data points for B-spline curve approximation.
Fig. 3 Approximated results of $f_1$, $f_2$, and $f_3$ respectively. The green dashed line represent data points(true function); blue dashed line is the approximation.

Table 4 Comparison of methods. Best results highlighted in bold.

<table>
<thead>
<tr>
<th>Authors, year and references</th>
<th>Method</th>
<th>Number of iterations</th>
<th>Test functions</th>
<th>Number of interior knots</th>
<th>AIC</th>
<th>BIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Galvez et al.(2015)[4]</td>
<td>Artificial immune systems</td>
<td>100</td>
<td>$f_1(t)$</td>
<td>4</td>
<td>1117</td>
<td>1157</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$f_2(t)$</td>
<td>8</td>
<td>1078</td>
<td>1144</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$f_3(t)$</td>
<td>5</td>
<td>1075</td>
<td>1121</td>
</tr>
<tr>
<td>Our method (2016)</td>
<td>Intelligent water drops (IWD)</td>
<td>12</td>
<td>$f_1(t)$</td>
<td>4</td>
<td>1086</td>
<td>1146</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$f_2(t)$</td>
<td>7</td>
<td>1021</td>
<td>1100.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$f_3(t)$</td>
<td>7</td>
<td>1014</td>
<td>1093</td>
</tr>
</tbody>
</table>
Table 4 summarizes our simulation results of B-spline curve fitting. Here, best results are highlighted in bold. Fig. 3 demonstrates the approximated results of all function that we tested for the best solutions visually. Fig. 4 shows the effect of the diversity rate on the AIC and BIC values of the experimental result for function $f_3$ as an example.

Our comparative results reported in Table 4 confirm that our method outperforms in terms of the fitting errors for the knot selection problem. The number of iterations used to obtain best fitting is nearly ten times lower than other method. By using the AIC and BIC error functions we also provide efficient procedure to determine the optimal number of interior knots.

VI. CONCLUSION

We proposed the use of this algorithm for solving curve fitting problem. The points have been accepted as cities and a number of IWDs were placed on the cities randomly. At the end of the algorithm, the best path followed by IWD was determined. In this study, the points on the path were accepted the best points that represent the curve optimally.

Metaheuristic approaches frequently used in optimization problems are very strong but the convergence slows down when the generations approach to optimal solutions. Because of this, the cost of the problem rises up. Proposed method solves this problem in the local search step of the algorithm. In this step, diversity rate is used to prevent hanging out the local minimum.

In this paper, performance of IWD algorithm is demonstrated by representing numerous test functions and simulations. As a result, the proposed algorithm converges fast to optimal solutions and finds good, efficient and satisfactory results.

ACKNOWLEDGEMENT

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Monitoring of Anxiety-Like Behaviors on Rats with Video Tracking Technology

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Abstract—Artificial sweeteners like MSG (MonoSodium Glutamate) model has been used anxiety-like behaviors on rats. The tracking of rat’s movements has broad applicability to questions in anxiety-like behaviors with different doses MSG injections (50 mg/kg/day, 100 mg/kg/day and 200 mg/kg/day) to rats. In this paper, in order to measure three types locomotor activity (line crossing, rearing, grooming), a video tracking software is used. The advantage of this type of tracking software is that it provides to give locomotor activity of rats in real-time. The experimental results obtained in this study have shown that learning and memory functions negatively affected in the brains of the rats an anxiety-like model. In addition, the visual tracking results demonstrate that video tracking system provides an accurate monitoring of rat’s behavior.

Keywords—Rat, locomotor activity, anxiety-like behaviors, MSG, computerized video tracking, animal tracking.

1. INTRODUCTION

The etiology of the behavioral disorders might be genetic, physical, developmental and also psychological or social as well. Neurological disorder appears mostly with anxiety disorder and depression. In animals, behaviors likely to anxiety can be identified through experimental open field test, light/dark test, elevated plus maze test, tail suspension test, forced swim test, social interaction task [1]. Open field test enables the evaluation of parameters such as line crossing, rearing, grooming and the defecation number in rats [2].

Studies in rodents have shown that the administration of MSG at the neonatal stage alterations in locomotor activity have been shown [3], [4]. Grooming duration and rearing counts can be used to assess anxiety-like and exploratory behaviors in rodents [5]-[7]. Following acute MSG administration, locomotor activity reduced, grooming increased, while rearing activity reduced at MSG doses [8]. Reduced locomotor activity can be considered a form of anxiety-like behavior [9].

The video tracking systems in open field tests (including mazes) has become a very popular technique for monitoring of anxiety-like behaviors on rats. The automated observation systems, which always work in the same way therefore behaviors are recorded more reliably, provide to researchers many behavioural information about animals. In literature, various types of the techniques can be found, including infrared photobeam detectors [10], [11], [12], [13], vibration detection [14], radio telemetry [15], radar [16] and computerized video analysis [17], [18]. However, video-based tracking systems using video cameras are currently the most common approach to achieve the task [19]. As video-camera technology has preferred to obtain the desired outputs, many automated video tracking methods have been developed [20]. In those methods, analog video signals are sent to video processing unit which detects peaks of the signal. The detected signals indicate contrast between the tracked animal and the background. Then the coordinates of the tracked animal are determined. Modern video tracking systems generally digitize analog video signals using frame grabbers. The digitized video frames is composed of pixels and each pixel has gray scale value [21]. The tracking procedure analyzes digitized frame in order to pick out the animal from the background. Then, the desired calculations are performed in order to explain the meaning of animal’s behaviour.

In this study, the anxiety-like behaviors are investigated using pharmacological activation model with MSG. The objective of this study is to evaluate the effects of neonatal exposure to MSG on locomotor activity with video tracking system.

This paper is organized as follows: In Section 2, material and method, which are designed here, are explained in detail. Section 3 presents the numerical results of the monitoring behaviors on rats with video tracking technique. The discussion and conclusions about the observation results are given in Section 4.
II. MATERIAL AND METHOD

In this study, in order to measure various locomotor activity (such as line crossing, rearing and grooming) an automated video tracking mechanism is designed.

A. Testing Procedure

The open field test setup consists of a square field with a dimension of $45 \times 45$ cm and it is lightened by 3 fluorescent bulbs. The top of the field is open to the ambient and the square field is bordered by white stripes each of 1 cm width, on a black colored background. Each of the experimental animals are brought to the center of the open field setup and released to move freely. Duration of the test is determined as 3 minutes during which the rats are observed closely and any of their behaviors are recorded as line crossing, rearing and grooming. Figure 1 shows the open field test area and the used video tracking mechanism is illustrated in Figure 2.

B. Experimental Animal Group

Rats that are included in the study, are subject to 8 sessions of MSG injections in total, in the order of 50 mg/kg/day (group number = 6), 100 mg/kg/day (group number = 6) and 200 mg/kg/day (group number = 6). Rats that are selected as the control group (group number = 6), are subject to the intraperitoneal serum physiologic.

C. Hardware and software equipment

Video data were processed with a PC (Windows 10 Pro platform, Intel Core i7-4600U CPU @ 2.10GHz 2.70 GHz processor). Video frames were obtained by Flaxes FC 1604 camera (30fbs/15fbs). The data processing algorithms were developed using MATLAB 2014b and Image Processing, Computer Vision toolboxes.

D. Data Analysis

To analyze the data, we used an analysis of variance (ANOVA) for multiple groups. More complex designs, such as one-way ANOVA with repeated measures or n-way ANOVA (additional factors: time, treatment, genotype, stress, etc), can also be used on behavioral studies of rats.

III. OBSERVATION RESULTS

In this section, the observed rat’s movements are illustrated separately in certain moments as shown in Figure 3. In addition, comparative tables related to locomotor activity are shown to discuss the behaviors of rats.

The video camera records the open field setup from the top where the rats are free in this area. Then, the camera signals synchronously are sent to a PC. The signals are digitized by frame grabbers. The video processing software analyzes each frame in order to distinguish the tracked objects from the background on the basis of their gray scale since the gray scaling is the fastest. The threshold values of the video signals, which are used to subtract rat’s image from the background, are set manually. Then, the coordinates of the animal are determined and recorded. Then, the monitoring of animal behavior is achieved in the open field maze.
activities such as rearing and grooming. The numerical results related to rearing are presented in Table 2.

Table 2. ANOVA values of rearing and descriptive statistics, referred to the open field test values of the rats, pre and post injections of MSG

<table>
<thead>
<tr>
<th>Control Group (n=6)</th>
<th>MSG50 (n=6)</th>
<th>MSG100 (n=6)</th>
<th>MSG200 (n=6)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pi Rearing time (sec.)</td>
<td>5.5±1.02</td>
<td>11.0±1.43</td>
<td>8.8±1.24</td>
<td>0.021*</td>
</tr>
<tr>
<td>Po Rearing time (sec.)</td>
<td>3.1±1.04</td>
<td>4.0±1.09</td>
<td>2.6±0.4</td>
<td>0.740</td>
</tr>
</tbody>
</table>

pi: pre injection, poi: post injection.
*p<0.05 (p-value is statistically significant).

As shown in Table 2, following acute MSG administration rearing activity reduced at higher MSG doses. However, grooming values (Table 3) of the rats are increased on the contrary, by statistically reasonable figures (p<0.05).

Table 3. ANOVA values of grooming and descriptive statistics, referred to the open field test values of the rats, pre and post injections of MSG

<table>
<thead>
<tr>
<th>Control Group (n=6)</th>
<th>MSG50 (n=6)</th>
<th>MSG100 (n=6)</th>
<th>MSG200 (n=6)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pi Grooming time (sec.)</td>
<td>16.5±1.78</td>
<td>19.1±9.41</td>
<td>26.0±12.11</td>
<td>0.218</td>
</tr>
<tr>
<td>Po Grooming time (sec.)</td>
<td>14.0±1.78</td>
<td>52.0±12.07</td>
<td>49.6±9.82</td>
<td>0.030*</td>
</tr>
</tbody>
</table>

pi: pre injection, poi: post injection.
*p<0.05 (p-value is statistically significant).

Following post injection of MSG, grooming is increased significantly at doses of 50 mg/kg/day and 100 mg/kg/day, respectively. It is known that the following acute MSG administration, locomotor activity reduced, grooming increased, while rearing activity reduced at MSG doses. Reduced locomotor activity is considered a form of anxiety-like behavior.

IV. DISCUSSION AND CONCLUSION

In the literature, studies based on the anxiety model are achieved on animals through injections of artificial sweeteners such as MSG [22], [23], [24]. In the present study, characteristics of anxiety like behaviors of rats are determined through the injections of MSG at repetitive dosages. Following to the MSG injections, when we monitored the behavioral characteristics of rats resembling to anxiety, we determined a statistically considerable decrease in the roaming time of the animals in the open field and a decrease in the number of rearing behavior. However, the number of grooming is increased in a statistically considerable scale. Similar results is provided that a decrease in the motor activity is argued in [25], [26].
As an overall result, we have observed that in the anxiety modeling of rats, over activation of astrocytes has a certain effect on the motor neuron functions of the animals. Additionally, we have observed that the neuronal development, neuronal survival and the synaptic plasticity are also negatively affected by the over activation of astrocytes. Computerized video-tracking results of rat’s behavior confirm that the locomotor activities are negatively affected on rats an anxiety-like model.

REFERENCES


A New Approach Based on Image Processing for Detection of Wear of Guide-Rail Surface in Elevator Systems

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Abstract—In this study, a system based on image processing has been developed in order to prevent wear on guide-rail surface in elevators. In the proposed method, real-time condition monitoring is performed by cameras using built-in system. The images of elevator guide-rail surface are captured via four digital cameras fixed onto elevator cab. The image-processing methods are applied on the images captured by cameras and hence the wears on the surface of guide-rails are detected. The surface of guide-rail is firstly detected in the proposed method. Then, image segmentation and mathematical morphology are applied on the image of guide-rail surface and the wears on the surface of rail are detected. The failure extent of the wear failures detected are calculated. By processing the images captured by four cameras during movement of elevator, the results for surface of guide-rails are obtained. Using these results, reporting is performed. An elevator prototype has been created in order to carry out tests for development of the proposed method. The tests have been conducted by fixing the built-in system and cameras onto this elevator prototype. It is considerably advantageous to detect the failures on elevator guide-rails through image-processing methods. Following a literature review, it is seen that the proposed method is a new approach.

Keywords—Elevator Systems, Fault Detection, Image Processing, Image Segmentation

I. INTRODUCTION

Elevators ensure transportation of people inside buildings and increase their life quality. High-rise buildings whose number is increasingly going up today has one or more elevator cabs to provide vertical transportation. A great number of people use elevators in many buildings such as business centres, hotels, hospitals and shopping centres daily. It is highly essential for the elevators used by many people daily to operate constantly. In the event of sudden failure of elevators during operation, people inside them face with a tough situation. Also, people have difficulty during the maintenance-repair period of elevators. Elevator system has counterweight system in order to balance the weight of elevator cab. A guide-rail system has been developed to limit the movements of elevator cab and counterweights on horizontal axis. When an elevator system is operational, cab and counterweight system move reversely. The common failures in elevators are usually seen in the components such as elevator guide-rail system, ropes and motors.

Today, when we take multi-storey buildings as an example, the fact that the elevator becomes out of service negatively affects the life of users and reduces the quality of life. In this study, it is aimed to repair the small failures that may occur in the elevator line without causing major failures through early detection. Thus, elevator companies will bring quality service to the elevator systems by gaining customer satisfaction. An elevator company with such a system will be preferred more by its customers. In this way, the fact that users are stuck in the elevator cages and the system becomes out of service will be prevented by eliminating the failures that may occur suddenly in elevators.

Today, most of the multi-storey buildings have elevator systems. Elevator systems are excessively used in the daily life. Elevators are used not only in buildings but also in dangerous places such as mines. In this study, a system has been proposed for the early detection of failures that may occur in the rail line, which is the most important component of the elevator. In the proposed system, it is aimed to produce accurate results by using digital cameras with image processing techniques without being affected by the environmental conditions. Elevator rail is fixed to the elevator shaft and is a unit which facilitates movement of the elevator. In the elevator system, the guide rails are used for the purposes of guiding the cage and counter weight separately in the vertical movements, minimizing its horizontal movements, protecting the vertical directions of the cage and counter weight and preventing its rotation. In this study, methods have been developed for the early detection of failures that may occur in the rails during the movement of the elevator cage.

The general structure showing the sample elevator system is given in Figure 1.

It is seen that similar studies are not available when a literature review is performed for the proposed method. When national theses are analyzed, we see how important the elevator guide rails are [1-4]. In the master's thesis, Serhat [1] carried out a thesis study about the stress analysis of guide rail consoles by mentioning the importance of the elevator guide rails. When we analyze the studies which have been carried out until today, studies have usually been carried out by elevator control and elevator component analysis [5].
Landaluze et al. [6] proposed the active noise control application for the elevator cages. They received results from the proposed algorithms by creating a sample experimental environment. Peiiliang et al. [7] proposed wavelet packet algorithm and fuzzy neural network based methods for the elevator brake systems. The proposed algorithms were applied for the different failures that occur in elevators. As a result of the experimental studies, successful results were achieved for the detection of the elevator braking failures. Zhang et al.[8] proposed a method based on failure detection in elevators. They created an information system for the failure events by explaining the elevator door failures. Zeng et al. [9] developed a elevator door control algorithm based on image processing. They created a system with a micro processor having camera on it, and they used it in the control operations of the elevator doors. Zhao et al. [10] carried out a study for detecting the failure in the elevator systems. They proposed a method for the detection of the failures by explaining the failures occurring in the elevator systems and the reasons for the emergence of these failures. Jiancan et al. [11] proposed a signal processing-based failure detection method for the detection of the failures in elevator machines. They performed failure detection by applying spectrum-based methods to the signals received from the elevator system. Hu et al. [12] developed a real-time knowledge-based detection system by using PLC controlled production systems. In the thesis study, Yimou [13] conducted elevator inspection and market research. Yimou developed a system for measuring the inspection and quality of the elevators in Deyang, China. In addition, various studies have been carried out in the elevator systems such as quality control, failure detection, inspection and condition monitoring. [14,15].

When the websites of the major elevator companies such as ThyssenKrupp, Klaemann, Otis, Kone and Schindler as well as the scientific studies in the literature were analyzed, it was seen that studies similar business idea were not available. When the existing studies in the literature are analyzed it is seen that the failure detection, control and condition monitoring methods are very important in the elevator systems. In this study, failure detection is performed by image processing techniques by developing much more different methods than the literature.

II. PROPOSED METHOD

In the studies carried out in recent years, about 152 thousand elevators have been inspected and nearly 63% of these elevators could not pass the quality level. These types of elevators often fail while using, endanger the life of users and lead to the disruption of their daily life. In the elevators used in hospitals, the lives of emergency patients are put at risk as a result of the failures that may occur while handling emergency patients. Besides, the failure of the elevators used in large businesses such as mines leads to disruption of the works and the people's lives are put at risk [16,17]. Early detection of the failures that occur in the elevators is very important to avoid such problems. In the proposed method, it is aimed to reduce the maintenance and repair costs by condition monitoring system, to prevent the major failures that may occur and to eliminate the user victimization. In addition, it is aimed to ensure energy saving by preventing the frictions that may occur in the rails as a result of monitoring the rails structures in the elevator lines by cameras. Sample images for the elevators rails are presented in Figure 2.

![Sample elevator rail images](image)

Fig. 2 Sample elevator rail images a) Robust rail image b) Curved rail image c) Rusty rail image d) Worn rail image

The robust, curved, rusty and worn rail image samples are presented in Figure 2. In this study, the detection of the failed parts of the worn ray images is performed. A sample elevator prototype was formed to detect the failed parts by image processing. The cameras were fixed on the elevator cage to monitor the rails on this prototype. The cameras fixed on the elevator cage are seen in Figure 3.
The images were taken by placing 4 cameras on the elevator cage as in Figure 3. The wear failures that occur on the elevator rails are detected by applying the proposed method on the image taken. A general flow chart of the proposed method is presented in Figure 4.

The opening operation is obtained as a result of applying the dilation processing right after the erosion processing on the image. The objects within the image and the gaps between objects are cleaned according to the size of the structural element. The mask matrix used for the opening operation in the proposed method is presented in equation 5 [20].

\[ X \oplus B = \{ p \in Z^2 : p = x + b, x \in X, b \in B \} \] (dilation)

\[ X \ominus B = \{ p \in Z^2 : p + b \in X, \forall b \in B \} \] (erosion)

\[ X + B = (X \ominus B) \oplus (B \ominus X) \] (opening)

\[ X \ast B = (X \oplus B) \ominus (B \oplus X) \] (dilate-erode) (5)

The flow chart of the proposed method is seen in Figure 4. Firstly, the rail surface is extracted as preprocessing on the image taken from the camera. A section with a size of 480x200 is taken from the image taken in 480x640 size. This section taken involves the rail surface image. The rail surfaces represent the same pixels on the continuous image because the cameras are fixed over the elevator cage. Therefore, the pixels belonging to rail surface are extracted in 480x200 size from the image. The obtained RGB rail surface image is transformed into gray format and then binary format [18,19].

The image was transformed into gray format and then binary format through the tests performed. The code particle given in Figure 6 is used for the estimation of the failure detection and the size of the failure.

The image in Figure 5.b was obtained by applying the opening operation to the normal image in Figure 5.a. In Figure 5.b, it is seen that small asperities on the rail surface were disappeared and the real failures appeared more clearly. After the opening operation, the failure detection and the size of the failure are estimated by taking into account the number of white pixels on the image. The code particle used for failure detection and the size of the failure is presented in equations 1, 2, 3 and 4 [20].

The image in Figure 5.b was obtained by applying the opening operation on the sample image taken in 480x200 size. This section taken involves the rail surface image. The rail surfaces represent the same pixels on the continuous image because the cameras are fixed over the elevator cage. Therefore, the pixels belonging to rail surface are extracted in 480x200 size from the image. The obtained RGB rail surface image is transformed into gray format and then binary format [18,19]. The image was transformed into binary format by using a specific threshold value. This threshold value was determined through the tests performed. The opening operation was performed as the mathematical morphology operation on the binary image. The mathematical expressions of the basic binary morphological operations are defined in equations 1, 2, 3 and 4 [20].

The flow chart of the proposed method is seen in Figure 4. Firstly, the rail surface is extracted as preprocessing on the image taken from the camera. A section with a size of 480x200 is taken from the image taken in 480x640 size. This section taken involves the rail surface image. The rail surfaces represent the same pixels on the continuous image because the cameras are fixed over the elevator cage. Therefore, the pixels belonging to rail surface are extracted in 480x200 size from the image. The obtained RGB rail surface image is transformed into gray format and then binary format [18,19]. The image was transformed into gray format and then binary format through the tests performed. The code particle given in Figure 6 is used for the estimation of the failure detection and the size of the failure.
III. EXPERIMENTAL RESULTS

Raspberry pi card having the features of “Broadcom BCM2836 ARMv7 Quad Core SOC (Quad-Core), 900 MHz processor speed and 1 GB RAM” was used in this study. The image processing was performed with "OpenCV" libraries by using "python" programming language on the Raspberry pi card. In addition, 4 cameras with 24 FPS speed were used to take the images. First of all, an experimental setup was developed to take the images and perform the test procedure. The developed experimental setup is presented in Figure 7.

Fig. 7 Development of the experimental setup

A system which was similar to a normal elevator structure was developed in Figure 7. This elevator structure has rails, ropes, elevator cage, counter weight system, control panel, asynchronous motor and sensors. The cameras were fixed over the elevator cage to take the images in the developed experimental setup as shown in Figure 8.

Fig. 8 Fixing of the cameras and the preparation of the test environment

As it is seen in Figure 8, the images are taken from the cameras fixed over the elevator cage. The erosion failures that occur on the rail surface are detected by applying the proposed method on the images taken. Two rail surface images including robust and failed are presented in Figure 9.

Fig. 9 Sample rail surface image a) Robust rail surface image b) Failed rail surface image

The robust and failed rail surface images are presented in Figure 9. The proposed method was applied to the robust rail surface image in Figure 9.a, and the obtained result is
presented in Figure 10.a. The proposed method was applied to the failed rail surface image in Figure 9.b, and the obtained result is presented in Figure 10.b.

In Figure 10.a, it is seen that the rail surface is robust and there is not any erosion failure. In Figure 10.b, it is seen that there is an erosion failure. The proposed method was tested for 4 cameras and the erosion failures on the rail surface were detected. The speed of the developed elevator prototype is about 0.60 m/sec. When the speed of the elevator was taken into account, the real time operation of the proposed method was evaluated as appropriate and it was seen that it was working successfully as a result of the tests performed. The real-time rail surface is monitored in the “Python Sheel” environment while the elevator is working. As in Figure 11, the size of the failure is monitored by performing failure detection in the “Python Sheel” environment while the elevator is working on a sample rail with erosion failure on the rail surface.

IV. CONCLUSIONS

Elevator systems have become an indispensable part of people in our day. Elevators are the means of transport which are beneficial to people regarding the transportation of loads and people. The fact that elevators are failed while working is one of the undesirable events. In particular, the fact that elevators are failed while people are using them reduces the quality of life. A new image processing-based method for the prevention of the elevator failures has been proposed in this study. The rail surface erosion failures that may occur on the rails, one of the critical components in the elevator systems, are detected. In this study, a sample elevator system was created and 4 cameras were fixed on the elevator cage. Whether the rail surface was robust or failed was detected and the size of the failure was estimated if it was failed, by applying the proposed method on the images taken from the cameras. When the proposed method is compared with the studies in the literature, it is seen that it is a new study and it can operate in real time. This study provides a basis for the future studies, and it is aimed to detect the erosion, cracking, warping and corrosion on the elevator rails in the future studies.

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Chemical Analysis Program for the Time of Flight Mass Spectrometry System
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Abstract— In this work, we present a computer program that reads, manipulates, analyses and stores the mass spectra obtained by using Laser Time of Flight Mass Spectrometry (L-TOF-MS) system described elsewhere. This program allows users to record the characteristic parameters of experimental data such as vacuum pressure, voltages, laser power, sample name etc. both manually and automatically. Also, the obtained mass spectra can be used to investigate chemical substances (NOx, SOx, organic molecules etc.) or can be used to real time identification of the sample differences for given material database (metal oxides, alloys, paintings, healthy and cancerous tissues etc.) by using different mathematical and statistical procedures (PCA, LDA, kNN etc.). We have recently presented a simple chemical analysis procedure by starting from reading raw MS data from oscilloscope using TCP/IP protocol and following data processing steps. We have a great success to reduce the numbers of steps and time duration consumed for the following procedure.

Keywords— Mass Spectrometry, Data Acquisition, Data Processing, Statistical Analysis, GUI, MATLAB

I. INTRODUCTION

Mass spectrometry is an analytical method and has a wide applications including; industrial quality control [1-3], pharmacology [4-7], isotope ratio determination [7-10] and space exploration researches [11-13]. Mass spectrometers consist of three units, which are an ionisation unit, separation unit and detector. The obtaining and interpretation of the mass spectral data have a great importance to reveal the molecular structure and laser ionisation/dissociation processes [14, 15].

Data analysis is the most time-consuming processes and manual data processing can cause the unintended human error, such as, reading or writing ion intensities, workspace (time – mass to charge ratio) conversion errors. In this work, we have presented the reducing the numbers of steps and time duration spend for the mass spectral analysis procedure.

II. BACKGROUND AND THEORY

Recent years, multivariate data analysis methods have attracted great attention due to the large experimental data sets obtained from different experimental methods, especially in mass spectrometry. Researchers obtain thousands of ion peaks (mass to charge ratio) in different intensities for multiple repetitions for each experiment. Thus, dimension reduction and selection of the data analysis methods (PCA, LDA, kNN etc.) became an important problem. In order to overcome these problems, new software tools was created similar to MCR-ALS (Multivariate Curve Resolution–Alternating Least Squares) toolbox programmed in MATLAB environment [16]. A similar program (FlavonQ) was developed to simultaneously analyse ultra-high-performance liquid chromatography (UHPLC) high-resolution accurate mass spectrometry –mass spectrometry (HR-AMS) data and UV-VIS spectrometry data in order to profile the flavonoids [17]. Recently, a user-friendly program (SIM-XL) was developed for structural protein characterization by using peptide cross-linking analysis method for tandem mass spectrometric data [18]. In proteomics studies, a GUI program (IPeak) also presented for identification of the peptides data obtained from LC-MS/MS method [19]. To identify TLC (Thin Layer Chromatography) information from MSI (Mass Spectrometry Imaging) data sets, a program (DetectTLC) was developed [20]. Homemade software or package programs were used for biological tissue identification [21] or cancer detection [22] by using mass spectrometry data.

III. EXPERIMENTAL SETUP

Experimental setup consists of laser systems, time of flight mass spectrometer and electronics. In our experiments, we are using high-intensity femtosecond/nanosecond lasers. In the scope of this work, we have used a femtosecond laser system (Quantronix, Integra-C-3.5, NY, USA) as an ionisation source. TOF-MS system was designed and built by our group; background pressure of the vacuum chamber can be pumped down to 10^-8 mbar. Ion signals were collected by using an MCP detector (El-Mul Technologies LTD., Israel). The details of the experimental setup were presented elsewhere [23, 24].

Mass spectra were recorded remotely via TCP-IP protocol and real time by using a four-channel oscilloscope (LeCroy Corporation, WaveRunner 64 Xi, NY, USA).

IV. RESULTS AND DISCUSSION

GUI of the mass spectrometry program consists of the subpages that are Experiment, Setup, Connection, Laser Diagnostics and Database Control, as shown in Fig. 1. In the experiment section, the user can write sample name, number of sampling and perform plotting mass spectra. Setup section
(given as an inset in Fig. 1) provides the user to recording experimental parameters such as electrode voltages, vacuum pressure and laser power. In the connection section, the user defines IP number of the oscilloscope to connect using TCP-IP protocol. In laser diagnostics section, the user can obtain real-time UV-VIS spectrum of the laser pulses (Fig. 2.) by using UV-VIS-NIR portable fiber-optic USB spectrometer (0.1 nm FWHM optical resolution, USB 2000+, Ocean Optics). In database control section, the user can load a database file for given directory from local drivers. The user can control and plot mass spectra for desired rows and each row corresponds to a mass spectrum (Fig. 3).

MATLAB .mat file. After selecting and opening database file, the program record raw experimental data that contain mass spectra as an ion intensity (intensity corresponds to voltage value read by the oscilloscope) versus the time of flight of the corresponding ion peak. The user has to calibrate the system by using equation \((m/z)=at^2+b\) to transform time of flight spectrum to mass spectrum to use m/z ratio for further spectral analysis [25]. For calibration, the user has to select two known peaks (H\(^+\) and C\(^+\) or CH\(_3\)\(^+\) peaks) to calculate constant a and b to convert all time points to m/z ratio. The peak selection on the mass spectrum is shown in Fig. 4. The user select first hydrogen ion peak and then carbon ion peak in Fig. 4 by using mouse cursor (appearing crosshair).

In the database control section, the user firstly uses “Load Database” button to and then select database file stored as a MATLAB .mat file. After selecting and opening database file, the program record raw experimental data that contain mass spectra as an ion intensity (intensity corresponds to voltage value read by the oscilloscope) versus the time of flight of the corresponding ion peak. The user has to calibrate the system by using equation \((m/z)=at^2+b\) to transform time of flight spectrum to mass spectrum to use m/z ratio for further spectral analysis [25]. For calibration, the user has to select two known peaks (H\(^+\) and C\(^+\) or CH\(_3\)\(^+\) peaks) to calculate constant a and b to convert all time points to m/z ratio. The peak selection on the mass spectrum is shown in Fig. 4. The user select first hydrogen ion peak and then carbon ion peak in Fig. 4 by using mouse cursor (appearing crosshair).
Following the time of flight spectrum transformation to mass spectrum, the user can view all collected mass spectra by using “MS Viewer” button, the opening window seen in Fig. 5. On the other hand, the user can investigate statistical results by using PCA visualization tool as seen in Fig. 6.

As a result, the fs-TOF-MS data sets were acquired as raw electronic signals, converted to digital values by using oscilloscope via TCP-IP. The obtained spectra were in the time of flight space first and after calibration, spectra were transformed into mass space.

We have got a great success to reduce the numbers of steps and time duration spend for the manual data processing procedures of the mass spectra analysis from weeks to seconds. Thus, we can eliminate the possibility of the unintended human errors appears in these manual procedures.

Within the context of this work, we built a backbone of the flexible program, which can be manipulated by customs needs, changing experimental setup and/or new unused statistical procedures in laser TOF-MS.

Analysing fs-TOF-MS data using multivariate statistical method, which suggests a new opportunity to use this program in real-time cancer detection research.

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A modified cuckoo search using different search strategies

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Abstract— Cuckoo search (CS) is one of the recent population-based algorithms used for solving continuous optimization problems. The most known problem for optimization techniques is balancing between exploration and exploitation. CS uses two search strategies to updating the nest: local and global search. Although cuckoo search are adequate for the exploration, it is not well enough the exploitation. Only one search equation is used for local search, this equation remains incapable and causes some deficiencies about the exploitation. To enhance the ability of exploitation and to balance between global search and local search, different search strategies were implemented in CS algorithm. The proposed method was compared with basic CS on well-known unimodal and multimodal benchmark functions. Experimental results show that the proposed method is more successful than the basic CS in terms of solution quality.

Keywords— Cuckoo search, continuous optimization, search strategies

I. INTRODUCTION

In the recent years, many novel nature inspired algorithm have been proposed to solve continuous optimization problems, alongside mostly known swarm intelligence algorithms such as particle swarm optimization [1], artificial bee colony [2], ant colony optimization [3] etc. The recent nature inspired algorithm was inspired by behaviours of animals in the nature. To illustrate, the firefly algorithm [4] was developed by flashing characteristic of fireflies, the bat algorithm [5] was proposed by being inspired behaviour of echolocation of bats. Yang and Deb [6] proposed the cuckoo search by being inspired breeding behaviour of some cuckoo species.

Cuckoo search (CS) is based on the obligate brood parasitism of some cuckoo species in combination with Levy flight random walk. Cuckoo search has been very popular in a short time and started to apply many engineering fields and optimization with promising efficiency and few control parameter settings. Due to these advantages, CS was used for clustering of web search results [7], hydrothermal scheduling [8,9], economic dispatch [10], multilevel thresholding [11], parameter estimation and optimization [12, 13], redundancy allocation problems [14], forecasting solar radiation [15] and so on.

The main problem of the optimization techniques is balancing between exploration and exploitation. The exploration is concerned the ability of autonomously seeking for the global optimum, whereas the exploitation is related to the ability of applying the existing knowledge to look for better solutions [16]. In other words, exploration represents global search and the exploitation stands for local search. CS has two search techniques and uses Levy flight rather than standard random walks for the global search. Thus, CS can explore the search space efficiently [17]. Although CS has local and global search capabilities, it opens to improvement about balancing between exploitation and exploration. In addition, due to some deficiencies about exploitation, strengthening the local search is more important for the CS. Many studies were performed to improve performance of cuckoo search. The cuckoo search parameters were properly tuned by Valian et al. [18] to enhance accuracy and convergence rate of the cuckoo search. Walton et al. [19] proposed modified cuckoo search which involves the addition of information exchange between the top eggs, or best solution. To improve refining ability and convergence rate of cuckoo search, Zhang and Chen [20] proposed the cuckoo search with adaptive method. This adaptive method was used to control the scaling factor and find probability to enhance the population diversity. A new cuckoo search algorithm based on the idea of opposition (OCS) algorithm is proposed by Zhao and Li [21] to increase the exploration efficiency of solution space. They merged the opposition-based learning in the CS and the proposed algorithm fully used beneficial information of the best solutions. In order to balance the exploitation and exploration of the cuckoo search algorithm, Li and Yin [22] proposed a new approach which uses two new mutation rules based on the rand and best individuals among the entire population. In addition, this new rules were combined through a linear decreasing probability rule. CS was used in hybridization with the other algorithm such as fuzzy c means [23], NEH heuristic algorithm [24].

To improve and enhance the performance of cuckoo search, we focus on ability of exploitation and some deficiencies of local search. CS uses only one search equation for the local search and this equation remains incapable and causes some deficiencies about the exploitation. To overcome this problem and balance between global and local search, different search strategies were implemented in the CS. Modified cuckoo search with the different search strategies (CSDSS) were compared with the basic CS on twelve benchmark functions. Experimental results show that the proposed method was more successful than the basic CS algorithm for both unimodal and multimodal functions. By virtue of different search strategies,
the CSDSS enhanced the efficiency of local search and improved the balance between exploration and exploitation.

The rest of the paper is divided as follows. In Section 2, the basic CS algorithm is presented. The proposed algorithm is detailed in Section 3. Section 4 gives the experimental results and comparison of the methods. As a final, the paper is concluded with the future works.

II. CUCKOO SEARCH

Cuckoo search was inspired by the interesting breeding behaviour such as brood parasitism of certain species of cuckoos by laying their eggs in the nests of host birds [6]. In the CS algorithm, there are mainly three principle rules as follows [6, 17]:

- Each cuckoo lays one egg at a time, and dumps it in a randomly chosen nest;
- The best nests with high-quality eggs will be carried over to the next generations;
- The number of available host nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a probability ps ∈ (0, 1). In this case, the host bird can either get rid of the egg, or simply abandon the nest and build a completely new nest.

For convenience, this last rules can be approximated by the fraction ps of the n nests are replaced by new nests (with new random solutions) [6]. Each egg in a nest stands for a solution and each cuckoo can lay only one egg. For the simplest approach of algorithm, each nest has only one egg. Thus, there is no difference between egg, nest and cuckoo. All of them represent one solution.

The CS uses two search strategies and two solution search equation to generate new solutions. One of them is local random walk and other one is global random walk. The global random walk is performed by the using Levy flights [17]

\[ x_{i}^{t+1} = x_{i}^{t} + \alpha L(s, \lambda), \]  
\[ L(s, \lambda) = \frac{\lambda \Gamma(\lambda) \sin(\pi\lambda / 2)}{\pi} \frac{1}{s^{\lambda+1}}, \quad (s \geq s_0 > 0) \]  

where \( \alpha > 0 \) is the step size of scaling factor and it is generally determined with \( \alpha = O(L/10) \), where \( L \) is characteristic scale of the problem of interest. On the other hand, the local random walk can be written as [17]:

\[ x_{i}^{t+1} = x_{i}^{t} + \alpha s \otimes H(p_s - \varepsilon) \otimes (x_{r}^{t} - x_{k}^{t}) \]  

where \( x_{r}^{t} \) and \( x_{k}^{t} \) are two different solution selected by randomly, \( H(u) \) is Heaviside function, \( \varepsilon \) represents random number drawn from a uniform distribution, \( p_s \) stands for switching parameter of controlling the balance between local and global random walk and \( s \) is the step size. The new nests are generated by the both of Eq. (1) and Eq. (3) in the every iteration. Detailed information about the cuckoo search, please refer to [6, 17].

III. MODIFIED CUCKOO SEARCH WITH DIFFERENT SEARCH STRATEGIES (CSDSS)

The CS can explore the search space efficiently thanks to Levy flights random walk. But one solution search equation is used for the local search and the best solution of nest is ignored by this equation. This causes lack of the exploitation. To strengthen and increase the efficiency of local search without losing the ability of exploration, different search strategies are implemented in the local random walk phase of the cuckoo search.

\[ x_{i}^{t+1} = x_{i}^{t} + \text{rand}(x_{i}^{t} - x_{j}^{t}) \quad i = 1, 2, ..., N, i \neq k \neq r \]  
\[ x_{i}^{t+1} = x_{i}^{t} + \Phi(x_{i}^{t} - x_{j}^{t}) \quad i = 1, 2, ..., N, i \neq k \neq r \]  
\[ x_{i}^{t+1} = x_{i}^{t} + \Phi(x_{i}^{t} - x_{best}^{t}) \quad i = 1, 2, ..., N, \]  
\[ x_{i}^{t+1} = x_{new}^{t} + \Phi(x_{i}^{t} - x_{j}^{t}) \quad i = 1, 2, ..., N, i \neq k \neq r \]  

Equation (4) is the same as local search update rule of the basic CS algorithm [17].In (4), (5) [25] and (7) [26], \( x_{i}^{t} \) and \( x_{k}^{t} \) are solutions randomly selected from the population at time step \( t \), and \( k \) and \( r \) are not equal to each other and \( i \). In (6) and (7), \( x_{best}^{t} \) in the equations is the best solution obtained by the population so far. Also, \( \Phi \) is a random number in range of \([-1,1]\] and produced for each cuckoo which is updated at the time step \( t \). To increase and protect the efficiency of exploration, the random neighbours are used in Eq. (4) and Eq. (5). Also, Eq. (6) and Eq. (7) are implemented to support the local search around the global best solution of population and enhance the ability of exploitation. The important point is how these equations are used together to obtain new solutions. Usage of these equations is explained by Fig.1.

\begin{verbatim}
for i=1: number of cuckoo
    if rand < ls_rate
        if rand < 0.5
            Generate new cuckoo with Eq. (7)
        else
            Generate new cuckoo with Eq. (6)
        end
    else
        if rand < 0.5
            Generate new cuckoo with Eq. (5)
        else
            Generate new cuckoo with Eq. (4)
        end
    end
end
\end{verbatim}

Fig.1 Usage of equations for the proposed method

In Fig.1, \( ls \_rate \) is the constant parameter in range of \([0,1]\) that controls the level of local search for the proposed method. If the \( ls \_rate \) is high, the proposed method searches the around of global best solution and makes more local search. The proposed method uses the algorithm in Fig.1 instead of the Eq. (3) in the basic CS to generate new solutions.
IV. EXPERIMENTAL RESULTS

In this study, all the experiments were run on a machine with Intel Core i7 2.40 GHz CPU, 8 GB RAM and the Windows 8 operating system and the codes were implemented in Matlab 2014 (8.3).

To examine the performance and accuracy of the CSDSS algorithm, the CS and CSDSS are applied to optimize 12 benchmark functions. The dimension is set 30 for all benchmark functions. Experiments are implemented with the population size of 40 for both algorithms. As a stopping criterion is used the maximum number of iteration and it is determined as 2500 in each run for each test function. While \( p_a \) parameter is set 0.25 for basic CS algorithm, it is determined as 0 for the proposed method. In addition, \( ts \) rate is used as 0.3 for the CSDSS as a result of the trials.

The determined benchmark functions are numbered \( f_1 \) to \( f_{12} \) given in Table 1. All the functions are to be minimized. Table 1 shows characteristic (C), search range (Range), and formulation of the functions. The cuckoos are initialized in the search range. The functions \( f_1, f_2, f_3, f_4, f_5, f_6 \) and \( f_{11} \) are unimodal and \( f_7, f_8, f_9, f_{12} \) are multimodal.

Table 2 contains a comparison of the original CS and the proposed method for the 12 benchmark functions listed in Table 1. Table 2 shows the mean result of 30 runs with 2500 iterations and dimension 30. The information about the mean optimum solution, standard deviation, minimum and maximum value and Wilcoxon test result by CS and CSDSS in 30 runs over benchmark functions are given in Table 2. The best mean result and the best standard deviations of the benchmark functions obtained by the algorithms are shown in bold. In the Table 2, in case Wilcoxon test was at 0.05 significance level, + mark was used, otherwise, - mark was used; NA was used in case all results showed the same value or optimum value.

### Table I

<table>
<thead>
<tr>
<th>Range</th>
<th>C</th>
<th>Function</th>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>[-100, 100]</td>
<td>U</td>
<td>Sphere</td>
<td>( f_1 = \sum_{i=1}^{n} x_i^2 )</td>
</tr>
<tr>
<td>[-10, 10]</td>
<td>U</td>
<td>Schwefel2.22</td>
<td>( f_2 = \sum_{i=1}^{n}</td>
</tr>
<tr>
<td>[-10, 10]</td>
<td>U</td>
<td>Rosenbrock</td>
<td>( f_3 = \sum_{i=1}^{n} [100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2] )</td>
</tr>
<tr>
<td>[-1.28, 1.28]</td>
<td>U</td>
<td>QuarticWN</td>
<td>( f_4 = \sum_{i=1}^{n} x_i^4 + \text{random}[0,1] )</td>
</tr>
<tr>
<td>[-5.12, 5.12]</td>
<td>M</td>
<td>Rastrigin</td>
<td>( f_5 = \sum_{i=1}^{n} [x_i^2 - 10 \cos(2\pi x_i) + 10] )</td>
</tr>
<tr>
<td>[-32, 32]</td>
<td>M</td>
<td>Ackley</td>
<td>( f_6 = -20 \exp\left(-0.5 \sqrt{\frac{1}{n} \sum_{i=1}^{n} x_i^2} + \exp\left(-\frac{1}{n} \sum_{i=1}^{n} \cos(2\pi x_i)\right) + 20\right) )</td>
</tr>
<tr>
<td>[-600, 600]</td>
<td>M</td>
<td>Griewank</td>
<td>( f_7 = \frac{1}{4000} \sum_{i=1}^{n} x_i^2 - \prod_{i=1}^{n} \cos\left(\frac{x_i}{\sqrt{i}}\right) + 1 )</td>
</tr>
<tr>
<td>[-50, 50]</td>
<td>M</td>
<td>Penalized2</td>
<td>( f_8 = \frac{1}{10} \left[\sin^2(\pi x_1) + \sum_{i=1}^{n} (x_i - 1)^2[1 + \sin^2(3\pi x_i)]\right] + (x_n - 1)[1 + \sin^2(2\pi x_n)] + \sum_{i=1}^{n} x_i )</td>
</tr>
<tr>
<td>[-100, 100]</td>
<td>U</td>
<td>Step</td>
<td>( f_9 = \sum_{i=1}^{n} \left(\left</td>
</tr>
<tr>
<td>[-100, 100]</td>
<td>U</td>
<td>Elliptic</td>
<td>( f_{10} = \sum_{i=1}^{n} (10 \cdot 6)^{-(i-1)/(n-1)} x_i^2 )</td>
</tr>
<tr>
<td>[-10, 10]</td>
<td>U</td>
<td>SumSquare</td>
<td>( f_{11} = \sum_{i=1}^{n} x_i^2 )</td>
</tr>
<tr>
<td>[-10, 10]</td>
<td>M</td>
<td>Alpine</td>
<td>( f_{12} = \sum_{i=1}^{n}</td>
</tr>
</tbody>
</table>

### Table II

<table>
<thead>
<tr>
<th>Func.</th>
<th>Opt.</th>
<th>CS Mean</th>
<th>CS STD</th>
<th>CS Min</th>
<th>CS Max</th>
<th>CSDSS Mean</th>
<th>CSDSS STD</th>
<th>CSDSS Min</th>
<th>CSDSS Max</th>
<th>Sign</th>
</tr>
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<tr>
<td>( f_1 )</td>
<td>0</td>
<td>1.14E-15</td>
<td>2.87E-10</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_2 )</td>
<td>0</td>
<td>1.71E-16</td>
<td>2.64E-12</td>
<td></td>
<td></td>
<td>3.22E-15</td>
<td>7.33E-10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_3 )</td>
<td>0</td>
<td>2.75E-05</td>
<td>1.10E-04</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_4 )</td>
<td>0</td>
<td>5.23E+01</td>
<td>2.03E+00</td>
<td></td>
<td></td>
<td>1.69E+00</td>
<td>8.21E-01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_5 )</td>
<td>0</td>
<td>5.01E-03</td>
<td>9.79E-03</td>
<td></td>
<td></td>
<td>5.70E-03</td>
<td>1.03E-04</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_6 )</td>
<td>0</td>
<td>2.01E-01</td>
<td>3.55E+15</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_7 )</td>
<td>0</td>
<td>8.14E+00</td>
<td>1.35E+01</td>
<td></td>
<td></td>
<td>3.81E+01</td>
<td>5.48E+01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_8 )</td>
<td>0</td>
<td>2.84E-02</td>
<td>3.53E-02</td>
<td></td>
<td></td>
<td>6.84E-01</td>
<td>5.48E+01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_9 )</td>
<td>0</td>
<td>5.32E+01</td>
<td>3.55E-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_{10} )</td>
<td>0</td>
<td>6.85E-05</td>
<td>6.04E+00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_{11} )</td>
<td>0</td>
<td>9.32E-05</td>
<td>2.95E-01</td>
<td>+</td>
<td></td>
<td>4.52E+00</td>
<td>1.73E-01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( f_{12} )</td>
<td>0</td>
<td>4.57E-04</td>
<td>0.00E+00</td>
<td></td>
<td></td>
<td>4.59E-01</td>
<td>1.33E+00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE**

RESULTS FOR BENCHMARK FUNCTIONS (OPT:OPTIMUM STD:STANDARD DEVIATION, MIN:MINIMUM, MAX:MAXIMUM, SIGN: STATISTICAL TEST SIGN)
When examines Table 2, CSDSS algorithm acquires better results compared to CS algorithm for the all benchmark functions except $f_3$ and $f_8$ in terms of solutions. The proposed method is more successful for the all unimodal functions. While ability of local search of CS algorithm remains incapable on the unimodal functions, the proposed algorithm makes more sufficient local search and obtains the better result than the CS. The CS algorithm is better than proposed method for $f_3$ and $f_8$ functions. But, the CSDSS gives the optimum results for the function $f_3$. Experimental results show that not only the CSDSS enhances the ability of local search but also improves the balance between exploration and exploitation. The proposed method outperforms the basic CS on the unimodal functions, at the same time it obtains better results the most known multimodal functions such as Rastrigin, Griewank and Ackley.

Non-parametric statistical test has been implemented for statistically significant of between CS and the CSDSS. From the results in Table 2, it can be observed that the CSDSS algorithm’s performance is significantly better compared to CS algorithm for all benchmark functions.

When examines Fig.4, the CSDSS outperforms the CS algorithm and reaches the optimum result very quickly. So, with respect to overall assessment of convergence graphs, we can say that the proposed method converges quickly and accurately towards the optimum solution.

<table>
<thead>
<tr>
<th>$f_{12}$</th>
<th>0</th>
<th>Max</th>
<th>Mean</th>
<th>STD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1.66E-09</td>
<td>6.14E-14</td>
<td>4.03E-14</td>
<td>7.11E-15</td>
<td>1.37E-13</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>1.43E-105</td>
<td>1.04E-106</td>
<td>5.71E-106</td>
<td>2.17E-13</td>
<td>3.13E-105</td>
</tr>
</tbody>
</table>

In order to compare convergence rates of the methods, convergence graphs for CS and CSDSS algorithms are given in Fig. 2, Fig. 3 and Fig. 4 for Schwefel2.22, Rastrigin and Griewank functions. The convergence graphs show that the proposed method has rapidly convergence and also obtains successful results. Examining Fig.2, while the CS converges slowly, the CSDSS continues the improving solutions thanks to ability of local search. For the Rastrigin function, the proposed method has early convergence and then gets stuck the local minima in Fig.3. Although its early convergence, it obtains better result than the basic CS.

V. CONCLUSIONS

In the basic CS, one solution search equation is used for the local search and the best solution of nest is ignored by this equation. This causes lack of the local search. In order to overcome these deficiencies of the CS algorithm in local search, this paper proposed the CSDSS algorithm using the different search strategies. Not only the proposed algorithm strengthens the ability of local search but also it improves the balance between exploration and exploitation. The proposed algorithm was compared with the basic CS on twelve benchmark functions. The CSDSS performs better results than the basic CS for all benchmark functions except $f_3$ and $f_8$. The proposed method is more efficient and more effective than the basic CS algorithm especially on the unimodal and some of multimodal functions.

As future work, the proposed method will be implemented to optimization problems and different search strategies will be used for the other nature-inspired algorithms. Furthermore, different search strategies can be increased and varied to improve the success of the proposed algorithm.

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REFERENCES


Video Stream With Websocket On Raspberry Pi
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Abstract—Internet of Things (IOT) and communication between machines (M2M), has emerged as an important concept in conjunction with the use of Internet technology in embedded systems. Thus, programmable remote control and the need for people with microcontrollers, it becomes possible to use the system are minimized. Given this device's web server hardware capabilities, also allows the use of technologies such as web sockets. In this study, a mini computer featuring Raspberry Pi 2 moving images received through the attached camera on, transmitting in real time with clients via the web browser and the ability to monitor the place where you have displayed to clients at the same time is designed as a system. The goal of this system, image processing and artificial intelligence methods using a remote place / region to create a hardware and software infrastructure for monitoring or monitoring. The target for the operating system that offers performance from the device with the use of minimal resources, non-graphical interface and development environment ARM-supported Debian Linux as the Node.js installation is preferred. Socket servers and HTTP server software made by users of a particular program without the need for mobile phone environment is installed the device in any environment with a computer or web browser to monitor in real-time, data retrieval, and has obtained the ability to check. Created this is the system to be monitored spaces regardless of the number of users, thanks to the web connector technology in the software encoded on the device in real time without requiring an additional operation in the browser monitoring displays alerts (voice, text, etc.) situation can be produced.

Keywords—Raspberry Pi, IoT, M2M, Embedded Linux, Windows 10 IoT, Tomcat 8, Spring Framework, JSF, Primefaces.

I. INTRODUCTION

Embedded systems, machines and the Internet of objects (IOT) communication (M2M) systems in the exercise, one of the problems is the ability of hardware and software of the card used. The card will be developed, based on powerful hardware of software capabilities and data directly to the success. Unlike the device used to this point IoT Raspberry Pi 2 stands out. Raspberry Pi 2 reminds of a small computer with its specifications [1],[2]. The features of the card:

- 900 mhz Broadcom bcm2836 armv7 quad core cpu,
- 1 gb sdram,
- 10/100 ethernet rj45 jack,
- 4 usb connector,
- hdmi video output,
- audio and video output,
- micro sd card slot,
- 45 gr weight,
- csi camera link ports,
- dsi display connector,
- general purpose input and output 40 pins,
- micro usb power input.

Raspberry Pi founded on the route that the operating system capabilities of the card and depending on the desired programming engine performance can be created. Thus, microcontroller’s language dependency, and programming language is a dynamic development environment which removes the version dependency is obtained. Therefore, the performance of the operating system to be installed on the card the Raspberry Pi card directly. Card will be selected according to the work to be done on the programming language of the work performed is a direct impact on the success and performance. Similarly in this study; Raspberry Pi 1 used to monitor traffic [3]. Raspberry Pi 1 Model B used for home automation system in another work [4].

II. OPERATING SYSTEM AND NODE JS

A. Operating System Selection and Installation

Raspberry Pi cards use ARM architecture processors. ARM processors are compatible with all operating systems can run on Raspberry Pi. But running compatible with hardware, card produced for Raspberry Pi operating systems is used more
libraries. Web socket technology used with a very available in the low to initialize language is created with the “WebSocket” objects with which new data exchange, a new connection must be created and a package is one of the Socket IO this work was used in the search over the package is used by adding to the project. as module. Node Js NPM. languages is the biggest advantage is the package m platform is easy to install. [7 of the nucleus so that it allo modular. Node Js in 2009 Joyent company by Google's V8 Javascript engine is produced with a typical run-time environment to be run by the server. Node Js is scalable, event-driven event-driven asynchronous, non-blocking I/O uses working model [6]. This also allows you to run with high performance. LinkedIn mobile server side after passing to Node Js Server dropped the number from 3 to 30 and up to 20 times faster in some operations in masterminding. Node Js are modular. As a module each Node Js library and shrink the size of the nucleus so that it allows applications to run faster [7]. Downloaded the file from the official website of Node Js platform is easy to install. According to other programming languages is the biggest advantage is the package manager Node Js NPM. Ask if you want to do what you want probably as module. NPM is located and easily the desired with the search over the package is used by adding to the project. This package is one of the Socket IO this work was used in the acquisition of data with the web socket.

B. Node Js

Node Js in 2009 Joyent company by Google's V8 Javascript engine is produced with a typical run-time environment to be run by the server. Node Js is scalable, event-driven event-driven asynchronous, non-blocking I/O uses working model [6]. This also allows you to run with high performance. LinkedIn mobile server side after passing to Node Js Server dropped the number from 3 to 30 and up to 20 times faster in some operations in masterminding. Node Js are modular. As a module each Node Js library and shrink the size of the nucleus so that it allows applications to run faster [7]. Downloaded the file from the official website of Node Js platform is easy to install. According to other programming languages is the biggest advantage is the package manager Node Js NPM. Ask if you want to do what you want probably as module. NPM is located and easily the desired with the search over the package is used by adding to the project. This package is one of the Socket IO this work was used in the acquisition of data with the web socket.

III. WEB SOCKET

When the HTTP protocol, web browser (client) from the server (web-server) an HttpRequest, HttpResponse from the server in return gets, the connection is closed. Again, for a new data exchange, a new connection must be created and a new request.HTML5 browsers that support Java Script language is created with the “WebSocket” objects with which to initialize the client-to-server, server-to-client-sided with a low-cost, persistent connections are created. In Java Script web socket technology used with a very available in the library [8]. One of them; “Socket IO” and “SockJs” libraries. In enterprise applications, has become widely used in the Java Spring Framework, STOMP protocol support with SockJs library. In this study, it has been the preferred socket IO library.

A. Socket IO

The socket IO's with almost every browser in real time (including mobile devices) in spite of different communication protocols to communicate study is preferred. On servers that have been created on the node Js platform Socket IO is used with ease. The socket IO library created from object is set to the specified port on the server is made ready for use by the rest.

B. Real Time Event Model

The Socket IO creates web socket objects. Sockets are created when request by client to the web server-side on the port opens a channel between the client and service (Fig 2).

Fig. 2 The socket IO client/server connection model

Connecting to a socket request pop-up web posted by all clients through data communications same channel (Fig 3).

Fig. 3 The socket IO client/server data exchange model

Depending on the socket, exchanging data between clients and the server, you can open the channel room performed. Data communication materializes “Unicast”, “Multicast” or “Broadcast” in channel (Fig 4).
1) **Multicast**: The message to be sent to clients only is desired.

2) **Unicast**: Exchange of messages between client-server only point-to-point.

3) **Broadcast**: The message is sent to all clients in the channel.

**Fig. 4** The socket IO client/server data exchange model 2

**IV. IMPLEMENTATION OF WEBSOCKET RASPBERRY PI 2 VIDEO STREAM**

The prepared implementation of the model split into two layers. Layers named “Hardware” and “Software” (Fig. 5). Raspberry Pi 2 Card and Raspberry Pi Pi Noir Camera used in hardware layer. Debian Linux OS, Node Js, Socket Io and Html 5 used in software layer.

**Fig. 5** Application Model

Pi Noir camera is different from a normally camera with some features. Pi Noir camera has not got infrared filter. Thus, light in different wavelengths of light environments detected by the camera [9]. Electronic pertinax card established consisting of infrared and rgb led for using features of Pi Noir camera (Fig. 6). Leds manage with Raspberry Pi gpio pins.

Led used on pertinax plate gives information about websocket communications.

**Fig. 6** Fritzing diagram which is used leds

The program is controlling open and closed status of leds used on the plate coded in Node Js platform. The means of types and colors of leds:

1) **Infrared led**: Use to capture at night.
2) **Rgb led blue light**: Use to display light’s purple and other rays
3) **Rgb led green light**: Websocket and informs that it expects clients in the operational position of the camera.
4) **Rgb led red lights**: It announces the formation of defects in the system

Debian Linux operating system boot (bootable) was written on an SD card that is compatible with the Raspberry Pi card. Pi Noir camera installed on hardware layer by Raspberry card’s CSI port (Fig. 6 and Fig. 7).

**Fig. 7** Hardware Implementation
Made and the installation of the card Node Js platform Raspberry Pi software development process was completed on the card. Images from a camera with software developed the web socket objects that were communicated to clients that connect to the so called html using (Fig. 9).

Fig. 9 Video stream

Written applications are listening for requests from port 8080. To access the application Raspberry Pi card is assigned a static "192.168.1.10" ip address. When you want to access the generated web application: between the client browser and the server establish socket connection called from a channel called "/jsws". The images from the camera push simultaneously to all clients. When the number of connections in the channel 0 application automatically adjusts the camera standby position. In night vision position by turning infrared leds provides image acquisition on the basis of sunrise and sunset times.

V. CONCLUSIONS

Raspberry Pi this system based on device that in terms of cost cheap and simple founded, without need for any additional software development it offers real-time video which can be monitored from any web browser or your mobile phone. Installed system image acquisition with the provision of day and night as well as used to monitor simultaneously zoology, science fields such as biochemistry. Adding to the installed system software image processing algorithms; scientific studies, in an environment that needs to be constantly monitored in everyday, the formation of unwanted alarm conditions occur. In our system operation of the infrared LED for darkness use of sunrise and sunset is the negative aspects of the work. This problem is solved by adding a light sensor in system. It offers flexibility improvements made on each layer of the work. The written application-layer architecture coding module provides convenience as the expansion of software. Image data obtained from this will be used in real-time face detection and identification operation

REFERENCES

COMPARISON OF SIMULATED ANNEALING AND GENETIC ALGORITHM APPROACHES ON INTEGRATED PROCESS ROUTING AND SCHEDULING PROBLEM

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Abstract— Today flexible manufacturing systems are highly popular due to their capability of quick response to customer needs. Although the advantages of flexible manufacturing systems cannot be denied, these systems also bring new issues on production planning side. Especially assigning machines to production operations and scheduling these operations with respect to machine constraints turn out to be an NP-Hard problem. In this study, the integrated process routing and scheduling problem is explained, and the performance of two different meta-heuristic techniques, which are genetic algorithms and simulated annealing, are compared in terms of solution time and quality.

Keywords— Optimization, Integrated Process Planning and Scheduling, Job Scheduling, Simulated Annealing, Genetic Algorithms

1. INTRODUCTION

Today, as the flexible manufacturing systems get more popular, scheduling production activities becomes more complex. The production managers have to make decisions such as: “Identifying the production operations that the jobs should go through”, “Assigning machines to job operations”, and “Identifying the sequence job operations on the machines”. Some of these decisions are related to the routing of the jobs on the shop floor and some of them are related to machine scheduling. These multiple aspects of production planning make the decision making much harder. Although it is possible to make decisions sequentially, this approach leads to a sub optimal solution. In order to find the best solution that minimizes the completion time of all jobs (makespan), the solution algorithm should take into account all aspects of the problem. This integrated production planning problem is referred as integrated process routing and scheduling problem in the literature.

It is possible to solve integrated process routing and scheduling problem optimally using the following mathematical programming model given by Botsalı and Şeker [1]. The model is described as follows:

- There is a set of jobs \( N \) and each job \( i \in N \) has a set of operations \( O_i \) to be completed,

- Any operation \( j \in O_i \) of job \( i \in N \) can be processed by a machine \( k \) of machine set \( M_j \) with process time \( t_{ijk} \).

- One machine can only process one operation of a job at a time and no preemption is allowed.

- The precedence relationship between the operations of a job should be satisfied.

- The objective is minimizing the completion time of the last operation (makespan) of the schedule.

By introducing the following additional variables and parameters, this problem can be modeled as below:

\[ Q : \text{Set of all machines} \]

\[ P_{ij} : \text{Set of operations that precedes operation } j \text{ of job } i \]

\[ (i \in N, j \in O_i, P_{ij} \subset O_i) \]

\[ x_{ijk} = \begin{cases} 1, & \text{if operation } j \text{ of job } i \text{ is processed by machine } k \ (i \in N, j \in O_i, k \in M_{ij}, M_{ij} \subset Q) \\ 0, & \text{otherwise} \end{cases} \]

\[ y_{ijlm} = \begin{cases} 1, & \text{if operation } j \text{ of job } i \text{ starts before operation } m \text{ of job } l \ (i, l \in N, j \in O_i, m \in O_l) \\ 0, & \text{otherwise} \end{cases} \]

\[ S_{ij} : \text{Start time of operation } j \text{ of job } i \]

\[ (i \in N, j \in O_i, S_{ij} \geq 0) \]

\[ C_{ij} : \text{Completion time of operation } j \text{ of job } i \]

\[(i \in N, j \in O_i, C_{ij} > 0) \]

\[ C_{\text{max}} : \text{Makespan (} C_{\text{max}} > 0) \]

\[ M : \text{A very big number} \]

Objective function:

(1) **Minimize** \( C_{\text{max}} \)

Subject to:

(2) \( \sum_{k \in M_{ij}} x_{ijk} = 1 \quad \forall i \in N, \forall j \in O_i \)

(3) \( C_{ij} = S_{ij} + \sum_{k \in M_{ij}} t_{ijk} \quad \forall i \in N, \forall j \in O_i \)

(4) \( S_{ij} \geq C_{lm} \quad \forall i \in N, \forall j \in O_i, \forall m \in P_{ij} \)

(5) \( S_{lm} - C_{ij} \geq (y_{ijlm} - 1) \times M \quad \forall k \in Q, i, l \in N, j \in O_l, m \in O_i; k \in M_{ij} \cap M_{lm} \)

(6) \( y_{ijlm} + y_{lmij} = 1 \quad \forall k \in Q, i, l \in N, j \in O_l, m \in O_i; k \in M_{ij} \cap M_{lm} \)

(7) \( x_{ijk} + x_{ijk} - y_{ilmj} - y_{mlij} \leq 1 \quad \forall k \in Q, i, l \in N, j \in O_l, m \in O_i; k \in M_{ij} \cap M_{lm} \)
In the above model, the objective is minimizing the makespan that equals to the finish time of the operation completed latest as stated by constraint set (8). Constraint set (2) ensures that each operation is assigned to a machine. Constraint set (3) defines that the completion time of an operation is equal to the sum of its start time and processing time. Constraint set (4) states the precedence relationships. Finally, constraint sets (5), (6), and (7) guarantee that operations processed by the same machine cannot be processed simultaneously.

This problem is NP-Hard and it becomes more and more difficult to solve the problem at the optimal level as the problem size gets larger. Due to this fact, in the literature there are various studies ([2], [3], [4], [5], [6], [7], [8]) to find a good solution in a short time for this problem using heuristic methods. In this study, we compare the performance of two different heuristics based on genetic algorithms and simulated annealing algorithm using the data instances provided by [2]. In the next section, details of these heuristics are provided.

II. HEURISTIC ALGORITHMS

The genetic algorithm used in this study was developed by Botsalı and Şeker [1]. Basically, this algorithm assigns a gene for each job that will be processed on the job floor. If there are \( n \) jobs and each job \( i \) has \( O_i \) operations to be completed on a production scenario, then the total number of genes in the chromosome of the respective individual in the population is equal to \( \sum_{i=1}^{n} O_i \).

Each gene in the chromosome has nine fields and each of these fields carries specific information as given below:

- Field 1: Order of the gene in the chromosome,
- Field 2: Job id that contain the corresponding operation
- Field 3: Order of the corresponding operation in the job id’s schedule
- Field 4: Id of the corresponding operation
- Field 5: Machine id assigned to the corresponding operation
- Field 6: Order of the previous gene in the chromosome which has the same job id in its Field 2
- Field 7: Order of the previous gene in the chromosome which has the same machine id in its Field 5
- Field 8: Start time of the corresponding operation
- Field 9: End time of the corresponding operation

II. HEURISTIC ALGORITHMS

The simulated annealing algorithm uses a data structure that is similar to the one used in the genetic algorithms. Also, the modification of the solution during the simulated annealing algorithm’s iterations are similar to the mutation operations of the genetic algorithm. During iterations, any new solution with a shorter makespan is accepted. However, a new solution with a longer makespan is accepted with probability \( e^{-(\text{makespan old}-\text{makespan new})/T} \), where makespan old and new are the makespan values of old and new solutions, respectively. \( T \) shows the temperature parameter of simulated annealing algorithm and it gets smaller as more iterations are done.

The algorithms are tested on a data set provided by Kim et al. [2]. However, there is an assumption we made which is different than the work done by Kim et al. [2]. We assume that two or more operations belonging to a specific job can be processed at the same time by different machines as long as there is no precedence constraint between these operations. By this way, integrated process routing and scheduling problem analysed in this study contains some characteristics of the assembly line scheduling problem. Yet, it is still possible to cancel this assumption and apply our algorithms to the original problem by just modifying the fitness/objective value calculation functions in the coding. Our computational results are given in the next section.

III. COMPUTATIONAL RESULTS

The genetic algorithm population size and the number of iterations is set to 100 and 150, respectively. Tournament size is taken as 3 and at each generation of the genetic algorithm 20% of the population is replaced by new individuals. For the simulated annealing algorithm, the maximum and minimum temperatures are set to 300 and 0.001, respectively. The cooling rate is set to 0.9 and at each temperature 10 iterations are done.

Both algorithms are run on a computer with Intel Core i5-5200U CPU@2.20 Ghz with 8GB Memory. For each instance, the algorithms are run 10 times and 10 different solutions are obtained. In Table I, the best solution values and the average of all solution values are provided for each algorithm and instance scenario.

As seen in Table I, the simulated annealing algorithm outperforms the genetic algorithm both in terms of solution quality and solution time when best solutions are analysed. Out of 24 instances, only for instance 11, the best solution of the simulated annealing algorithm is \( 0.1 \) higher than the genetic algorithm solution. In two instances, best solutions of the simulated annealing and the genetic algorithm are same and for the rest of the instance runs, the simulated annealing algorithm solutions are better than genetic algorithm solutions.

When the algorithms are compared in terms of average solution quality, except three instances, again solutions of the simulated annealing algorithm are better than solutions of the genetic algorithm. For these three instances, the average of simulated annealing solutions are at most 1.8% larger than the average of genetic algorithm solutions. However, for the remaining instances, the average of the solutions given by the simulated annealing algorithm can be up to 7.1% better than the average of the solutions given by the genetic algorithm.
Finally when two algorithms are compared in terms of solution time, the simulated annealing algorithm’s solution time is in general 90% shorter than the solution time of the genetic algorithm. In fact this is something expected since the number of computations is higher in the genetic algorithm.

During genetic algorithm computations, it is observed that the population converges to final solution before the 150th generation, so it may be possible to shorten the solution time of the genetic algorithm a little bit by reducing the number of generation parameter value from 150 to a lower value. Yet, still it is not possible for the genetic algorithm to be as effective as the simulated annealing algorithm in terms of computation time.

### TABLE I

<table>
<thead>
<tr>
<th>Instance No</th>
<th>Simulated Annealing Algorithm</th>
<th>Genetic Algorithm</th>
<th>% Improvement in Genetic Algorithm</th>
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<td>Best Makespan</td>
<td>Avg. Makespan</td>
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### TABLE II

<table>
<thead>
<tr>
<th>Instance No</th>
<th>SA Average Time (Seconds)</th>
<th>GA Average Time (Seconds)</th>
<th>% Improvement in Genetic Algorithm Solution Time</th>
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<td>11.64</td>
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<tr>
<td>24</td>
<td>21.19</td>
<td>314.25</td>
<td>93.3%</td>
</tr>
</tbody>
</table>

Although both algorithms used in this study are heuristic algorithms and they do not guarantee the optimal solution in the end, it is interesting to see that the simulated annealing algorithm gives better results compared to the genetic algorithm in general. There may be several reasons behind this. The author thinks that one of these reasons may be the size of the solution space. Since the number of the variables is very large in an integrated process routing and scheduling problem, it is
difficult for a heuristic algorithm to explore the whole space. For this reason, the quality of the final solutions highly depend on the initial solution(s) that the heuristic algorithms start from. As stated in the previous section, the genetic algorithm starts with a set of solutions which contain 100 different solutions (initial population). These 100 solutions are at different quality levels. The tournament selection procedure of the genetic algorithm gives higher chance to good quality solutions to be involved in crossover process. However, it seems like this is not enough to explore the parts of the solution space containing good quality solutions. On the other hand, the simulated annealing algorithm, starts with the best solution chosen out of an initial solution set of 100 solutions. It is seen that searching the solution space starting with a good solution and putting all the computational effort on one promising solution lead the simulated annealing algorithm to be superior to the genetic algorithm.

IV. CONCLUSION

In this study, two different algorithms are compared for the integrated process routing and scheduling problem. These two algorithms are based on genetic algorithm and simulated annealing algorithm techniques. The algorithms are tested over the problem instances provided by Kim et. al. [2]. It is observed that the simulated annealing algorithm has better performance than the genetic algorithm in general.

It is possible to extend this study in various directions. Different assumptions such as the allowance of pre-emption on shop floor can be considered. Also the performance of different heuristic algorithms such as particle swarm optimization or tabu search can be compared.

REFERENCES


Transmit Power Control (TPC) Algorithm for LTE-A Femtocell Networks

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Abstract—3GPP LTE-Advanced release-13 is now supporting the deployment of femtocells (HeNBs), which provide better connectivity to the users (UEs) at home, offices, shopping malls, and dense urban areas, where the macrocell (eNB) has weak signals strength or no signal. These femtocells cover short distance (10 ~ 20 m) with high throughput and increased capacity, while on the other hand the deployment of huge number of femtocells create co-tier and cross-tier interference issues. To mitigate the co-tier interference problem we propose a Transmit Power Control (TPC) Algorithm, which will establish and control the connection between femtocell and the users. In case of downlink and uplink scenarios the transmit power of femtocells and UEs will be monitored accordingly. As a result this data will help to manage the switching of users among femtocells, macrocells to femtocells and vice versa. In the end we show the simulation results to compare the SIR and Throughput of users.

Keywords—3GPP, LTE-A, Femtocell, Macrocell, RRM, UE, eNB, HeNB, SIR, Throughput

I. INTRODUCTION

3GPP LTE-A is a very promising 4G technology for the thirsty mobile cellular network. With the advancement of mobile communication and technology, the expectations for high data rates are also increased. Due to the huge growth of smart phones, tablets, and notebook etc. the quality of service (QoS) and ubiquitous connections are required. On the other hand the number of subscribers increasing every year dramatically. According to [1] Global LTE passed 1 billion subscriptions in 2015 and will reach up to 3.62 until 2020. Due to the explosive growth of users and multimedia services the main challenge for next generation cellular networks is to oblige mobile data traffic by improving the capacity of the networks [2]. The present LTE-A system is based on homogeneous network, where every single eNB cover the whole cell, and each eNB use similar transmission power levels, modulation techniques, access schemes, antenna patterns to offer QoS to the UEs across cell [3, 4]. However, such deployment degrades the coverage and capacity of the cell-edge users.

One approach to solve the above mentioned problem is to shrink the cells, it provide the high data throughput and can fulfill the increasing demand of cellular systems, which will also improve the interference and signal to noise ratio (SNR), but this approach is not economical and as a result its need lot of expenses [5]. Therefore, the deployment of heterogeneous network (HetNet) is more scalable and beneficial for both operators as well as users. This approach is expected not only to improve the broadband user experience but also increase the coverage and capacity of the cell in cost effective manner [3].

Fig. 1. Source: 3GPP Release 13 [6]

Small cells can support wireless applications for homes and enterprises as well as metropolitan and rural public spaces. Due to the smaller coverage area, the same licensed frequency band can be efficiently reused multiple times within the small cells in a HetNet (Figure 1), thus improving the spectral efficiency per unit area (and hence the capacity) of the network. In a HetNet, small cells are envisioned as traffic off-loading spots in the Radio Access Network (RAN) to decrease the congestion in macrocells, and enhance the users’ QoS experience [7].

There are different types of small cells included like femtocells, picocells, and microcells, in this paper we focus only on femtocells, which are denoted by Home evolved Node Base-Station (HeNB) in LTE-A, this low power device can be installed at Homes, Shopping Malls and Congested Urban Areas and managed by the user himself. It covers up to 20 to 30 meters distance of space; it is very useful for indoor communication where macrocell (eNB) coverage is not enough for customers. The main advantages of using HeNBs are low cost, IP backhauling and frequency reuse; provide high capacity. Low battery usage and seamless transition between wired and wireless connecting devices [8]. However, in order to successfully deploy the femtocell architecture several challenges need to be addressed. Interference management remains one of the major issues: femtocells which operate in the same spectrum of macrocell users produce a cross-tier interference which degrades their transmissions. Moreover,
neighbour femtocells which belong to same operators, which may interfere each other. The latter interference is known as co-tier interference [9]. In this article we propose an algorithm for co-tier interference management to avoid the interference between neighbour HeNBs and UEs.

In the preceding sections we discuss different approaches and techniques use for RRM; in Section III we proposed an algorithm, in Section IV we have simulation results and Section V is the conclusion.

II. RELATED WORK

These days the Radio Interference Management (RRM) in LTE-A femtocell is the most challenging issue for cellular network operators. This is also a very hot topic for wireless communication researchers. Some of the works done by researchers are discussed below.

The authors of the article [11] explained the orthogonal and co-channel frequency allocation schemes, compared them and also show the simulations results. According to the distance between HeNB and eNBs which are two coverage areas, where the spectrum of eNBs is different from the HeNBs. The [12] use the hybrid approach for both uplink and downlink interferences, in this article the use of shared spectrum is exploited only when this approach is favourable both to eNB and HeNB users; otherwise, the partitioned approach is chosen. A power control method are proposed in [13], the authors explain the uplink and downlink scenario, which limits the co-tier interference in, while the encroachment of co-tier interference is ignored. In [14] two possible solutions are highlighted, the first one is to use the separate spectrum for HeNB and eNB, this technique is said to be Dedicated Channel deployment, while the other approach is to use the same spectrum for HeNB and NBs, this is known as Co-Channel deployment technique. These solutions are good to sufficiently increase the overall capacity of the system, but the Co-Channel interference issue remains the same, and the deployment is costly for operators. Whenever HeNB and eNB share the same part of spectrum, they will interrupt each other. Article [15] proposed a systematic way to optimize the resource allocation for public femtocell networks, including three schemes of different stages: (1) long-term resource management, which is to allocate spectrum resource between eNB and HeNB networks; (2) medium-term resource management, which is to allocate radio resources to each HeNB; (3) fast resource management, which is to further enable multiple HeNBs to cooperate to improve the network’s coverage and capacity. As we know that cross-tier interference can also be minimize by interference cancellation, and this method is by [16] as the class of techniques that demodulate/decode desired information, and then use this information along with channel estimates to cancel received interference from the received signal. The key technique for interference avoidance is Transmit Power Control, especially when many HeNBs are installed very close to each other. One such approach is discussed in [17], where the transmit power of a HeNB can be utilized accordingly, while the outdoor eNB’s UE can be protected sufficiently. In article [18], the authors use a simple power control method to avoid the interference cause nearby eNB’s users.

III. EXISTING NETWORK AND ITS PROBLEM

According to [06], the users can install femtocells under a macrocell and share the same spectrum. In this paper, we studied the downlink and uplink co-channel interference when macrocell and femtocell share the same spectrum. The deployment configurations are CSG and co-channel. Specifically, the downlink transmissions from the femtocell will cause strong interference at a nearby macrocell’s UE and may cause the received macrocell signal at the macrocell’s UE degraded and become unacceptable. Hence, the co-channel interference is one of the major barriers for the successful co-existence of macrocell and femtocell. We address the downlink and uplink interference problem by considering the transmit power at both the macrocell’s UEs and the femtocell’s UEs in terms of their received SINR.

IV. PROPOSED ALGORITHM

As we discussed in above section many techniques are implemented in LTE-A femtocell networks to mitigate the interference problem, all these techniques are working very good but they have some limitations as well. In this paper we proposed Transmit Power Control (TPC) Algorithm, which would reduce the co-tier interference for uplink and downlink of the LTE-A femtocell system. The “Interference Avoidance” is used to reduce the system interference. Our proposed algorithm will avoid the interference based on the threshold value of Transmit Power of User Equipment (PT(UE)) and Home evolved Node Base-station (HeNB). PTUE represents Transmit Power of UE while PTHENB represents Transmit Power of HeNB and their values are pre-calculated. The PTUE of one specific HeNB is changing by the other HeNB which are deployed near to it, and these power levels are expressed in dbm. The uplink interference could be controlled and maintained by the HeNB Gateway Server, the UE under the particular HeNB should transmit the assign power as soon as possible, because the HeNB will connect on First Come First Serve (FCFS) basis. The HeNB uses pilot signal to detect the UE in its coverage area and set the Pilot bit (Pbit) to 1. After successfully established the connection the HeNB will instruct the UE to communicate at assigned transmit power level. In case of downlink, the HeNB power levels are registered on start-up in femtocell gateway (FG) center and the power within the power level assigned to each downlink channels of the particular HeNB it handles.

V. FLOW CHART

The backhaul of LTE-A femtocell and connections are explained in [19], the HeNB is initially connected with FG Server through ADSL or fiber optic and then it will further connect to ISP. The figure 2, explaining the algorithm how it works.

Step 1: When the femtocell (HeNB) is Switch ON. It will refresh/update its database and all values will set to “0”. At the same time the HeNB will be registered in FG, which will assign a unique identification number (ID) to the particular HeNB to recognize with its Transmit Power (PTHENB).

The HeNB will adjust the UE to set the specific transmit power level.
Step 2: The HeNB will set PTHeNB to 1, while in FG the (PTHeNB) will set on First Come First Serve (FCFS) basis.

Step 3: For Uplink there are many UEs i.e i=1,2,3,…,N and single HeNB. If the set value of PTHeNB is less than PTUEi, the connection will establish, otherwise the PTHeNB will be set according to new PTUE.

Step 4: If the new PTUEj is greater than PTUEi, then the PTHeNB will set according to new value, otherwise rejected.

Step 5: Downlink side, the FG will set the threshold value of HeNB in its database. If the PTHeNB is less than the threshold PTTH value, the connection will establish, otherwise rejected.

Step 6: We consider many HeNBs i.e (i=1,2,3,…,N) while single UE. If the new PTHeNBj is greater than PTHeNBi, then the database of FG will update according to new value, otherwise its value will remain the same.

Step 7: If the HeNB is Switched OFF, all the data will clear, otherwise it will repeat step 5.

VI. SIMULATION RESULTS

As for the 3GPP Release 13, we used LTE System Toolbox functions to generate a downlink Reference Measurement Channel (RMC) R.12. [20], to estimate the performance of the near and far femtocells UEs. The UEs which are near to HeNB receive high throughput while the far UEs receive low throughput in LTE femtocell system. To see the simulation results we assumed two different scenarios according to the transmitting power of the HeNBs.

The topology of the LTE-A femtocell system is shown in Figure 3. There are two femtocells (HeNB 2 and HeNB 3) under the range of one macrocell (eNB). These two HeNBs are very close to each other, which can be disturbed due to interference of the signals. To avoid the co-tier interference problem, we proposed an algorithm and can see the result of UEs and HeNB which are using different level of transmission power. There are four different users (UE 1, UE 2, UE 3 and UE 4) and they are using different transmission power. In the simulation we also use three different groups according to populations of the UEs, which are served by macrocell i.e (eNB). The three different groups are divided by Dense Populated (DP Group), Medium Populated (MP Group), and Less Populated (LP Group).

As for the HeNB-2 scenario is concerned, we have given high transmit power to UE 2 and low transmit power to UE 1, UE 3 and UE 4. In figure 4, the overall throughput is shown; where we can see the UE 2 throughput is higher than the rest of the other UEs. Which means the higher transmit power has high throughput and low transmit power has low throughput. On the other hand if there is less population then the throughput will be high, and vice versa. In the delay case, if the transmit power is high and population is less, then delay will also be less, and vice versa.

As for the HeNB-3 scenario is concerned, we have given less transmit power to UE 2 while on the other hand we have given high transmit power to UE 1, UE 3 and UE 4. Figure 5 showing the throughput result of the UEs of HeNB-3. We can
see in this figure, that the UE 1, UE 3 and UE 4 have high throughputs, while the UE 2 has low throughput. From these results we can say, that high transmit power has high throughput; while low transmit power has low throughput. Similarly DP Group has low throughput, while LP Group has high throughput. On the other hand if there is high transmit power and LP Group the delay would be quite low, and vice versa.

From the above simulation we can describe, that transmit power of femtocell (HeNB) is very important and will decide the communciation between HeNB to HeNB and UEs. The transmit power of both UE and HeNB will decide the connections between them. In our proposed algorithm, we use the transmit power of femtocell (HeNB) as a decider for both Uplink and Downlink scenarios. Higher the transmit power has higher chance of connectivity; lower transmit power will be rejected.

VII. CONCLUSION

The evolution in LTE-A, the deployment of femtocells (HeNBs) is of great improvement due its efficiency and low power consumption. In this article we proposed a Transmit Power Control (TPC) algorithm, which can work very intelligently to decide the connection between HeNB and UEs. Using this algorithm the co-tier interferences will eliminate and provide better performance. In the simulation section we discussed the importance of transmitting power of UEs and HeNBs in LTE-A femtocell networks; if the power is high the throughput is also good. In future we can propose some techniques (algorithms) for cross-tier interference which also affect the performance of femtocell network.

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CUSTOMER SATISFACTION USING DATA MINING APPROACH

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Abstract— Customers and products are the main assets for every business. Companies make their best to satisfy customers because of coming back to their companies. After sales service related to different steps that make customers are satisfied with the company service and products. After sales service covers different many activities to investigate whether the customer is satisfied with the service, products or not? Hence, after sales service is acting very crucial role for customer satisfaction, retention and loyalty. If the after sales service customer and services data is saved by companies, this data is the key for growing companies. Companies can add value their brand value with the managing of this data. In this study, we aim to investigate effect of 6 factors on customer churn prediction via data mining methods. After sale service software database is the source of our data. Our data source variables are Customer Type, Usage Type, Churn Reason, Subscriber Period and Tariff The data is examined by data mining program. Data are compared 8 classification algorithm and clustered by simple K means method. We will determine the most effective variables on customer churn prediction. As a result of this research we can extract knowledge from international firms marketing data.

Keywords— Data Mining, Customer Churn Prediction, Customer Satisfaction, Knowledge Discovery in Database

I. INTRODUCTION

Telecommunication companies maintain and store tremendous amount of data about the customer information, phone calls and the operations of their networks. Due to the improvement of computer systems and telecommunication technologies, this industry has expanded rapidly. Data mining helps to improve quality of service, detect the customer communication type, determine deceitfulness activities and make better use of resource in telecommunication industry.

One of the widely applied areas of data mining is Customer Relationship Management. Customer Relationship Management approach is focuses on retention, relationship development and increase satisfaction. From a business intelligence perspective, churn management process under the customer relationship management (CRM) framework consists of two major analytical modelling efforts: predicting those who are about to churn and assessing the most effective way that an operator can react (including ‘do nothing’) in terms of retention [1]. Previous studies have indicated that the cost of gaining new customers is much expensive than the cost of retention the existing customers [1], [2], [3], [4], [5], [6] Loss of customer causes negative effects on firms reputations and income reduction [7]. Companies are increasingly focused on accurate customer churn forecasting models. These models should be enhanced to identify the factors to churn and the developed needs to retain customers. Churn of customer is defined as the tendency of customers to interrupt doing business with a firm in the time process. Customer churn has become a significant problem today. In worldwide, one of the main challenges is determined to propensity of churn of customers. Geppert (2003) suggest another list of causes of churn: Price, Service quality, Fraud, Lack of carrier responsiveness, Brand disloyalty, Privacy concerns, Lack of features, New technology introduced by competitor, New competitor enter the market, Billing or service disputes [8].

High customer churn risk is one of the stringent challenges in telecommunication companies. Pareek has classified telecommunication industry challenges in four groups; Consolidation, Competition, Commoditization, Customer service. Telecommunication data which is very complex has needed many preprocessing for analyse. Data mining which is a useful tool, is extracting and exploring information from data. In this paper, we will provide an application to telecommunication companies. We want to have knowledge about customers that who are existing and loyal to company, who are going to leave or quitting from company products/services.

Customer churn probability is predicted by data mining algorithms analysing historical data. Data mining techniques used for this purposes typically utilize the average number of calls, billing data, the change in the average number of calls, call detail data, subscription and customer information [10].

In this paper, we investigate features of applying the data mining in customer churn prediction of a telecommunication data. First, we identify the variable of effecting customer
churn prediction of a telecommunication system. These variables are examined in data mining algorithms. Data mining algorithms are compared with each other. Proposed algorithm is also discussed and we conclude the paper with conclusions.

II. MATERIAL AND METHOD

Telecommunication data consist lot of interesting issues for analysing in data mining. Telecommunication databases include huge amount of data in worldwide. But raw data is not usually suitable for direct usage for data mining. For this reason researchers should examine data effectiveness and apply some of pre-processing operations to be usable. Our study include of data sampling, pre-processing, model construction, and model evaluation phases.

We have used open-source data mining tool Weka (version 3.8) for this study. We analyse our dataset performance of a comprehensive set of classification algorithms (classifiers).

A. Data Set

The dataset that we used obtained from a Turkey’s one of the biggest telecommunication company. Real time data was obtain on May 2016. Untreated data consisted of 6 factors, 66 sub factors and 498,866 instances. 38.36% of data were churners.

Evaluate factors is following;

<table>
<thead>
<tr>
<th>Variable</th>
<th>Code</th>
<th>Variable</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Type</td>
<td>Active</td>
<td>Subscriber Period</td>
<td>0-5</td>
</tr>
<tr>
<td></td>
<td>Churn</td>
<td></td>
<td>6-10</td>
</tr>
<tr>
<td>Usage Type</td>
<td>H</td>
<td></td>
<td>11-15</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td></td>
<td>16-</td>
</tr>
<tr>
<td>Churn Reason</td>
<td>1</td>
<td>Tariff</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>other</td>
<td></td>
</tr>
</tbody>
</table>

According to (Acker, et al., 2013), data pre-processing can be up to 80% of the total analysis work and analyzing the data, once joined, cleaned and transformed consumes just about 20%. The raw world data is usually noisy, inconsistent and incomplete due to their typically large size and their likely origin from multiple and heterogeneous sources. Dimensions of data quality; Accuracy, Completeness, Consistency Timeliness, Believability, Value added, Interpretability Accessibility.

Data sampling randomly selects a set of customers with the required information, according the definition of churn in designated telecommunication company. Evaluate factors and sub factors distribution as shown in Fig. 1.

![Fig. 1 Distribution of the data](image)

![Fig. 2 Major data pre-processing tasks and techniques](image)

In the study we used some of pre-processing techniques. In data cleaning step we clean some of the data, which are identifying incorrect information or incorrect. At the end of this step, we have 498.356 data. Ordered sub factors are converted to numeric values. We create some of groups of subscribe period for subscriber time.

B. Data Mining Techniques in WEKA

Data mining technique in CRM is usually apply in real world case because CRM on data mining have attracted both the practitioners and academicians. In CRM there are several
different functionalities, techniques and applications. as shown in TABLE II.

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Technique</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Association</td>
<td>Set Theory, Statistics</td>
<td>Cross Sell</td>
</tr>
<tr>
<td></td>
<td>Bayesian Classification</td>
<td></td>
</tr>
<tr>
<td>Estimation</td>
<td>Neural network, Time series</td>
<td>Exchange rate estimation</td>
</tr>
<tr>
<td>Classification</td>
<td>Decision Tree, Neural network</td>
<td>Credit embezzle</td>
</tr>
<tr>
<td></td>
<td>Genetic Algorithm</td>
<td>Market segmentation</td>
</tr>
<tr>
<td>Prediction</td>
<td>Regression, Decision Tree</td>
<td>Churn Prediction</td>
</tr>
<tr>
<td></td>
<td>Neural network</td>
<td>Fraudster prediction</td>
</tr>
<tr>
<td>Segmentation</td>
<td>Statistics, Genetic Algorithm</td>
<td>Market segmentation</td>
</tr>
</tbody>
</table>

For churn prediction is used most popular ones are:
- Decision trees
- Artificial Neural networks
- Regression.

Weka (Waikato Environment for Knowledge Analysis) includes some of classifier algorithm such as Bayes, MISC, Functions, Rules, Decision Tree, Lazy etc. A good mix of algorithms have been chosen from these groups that include Naive Bayes and Bayes net from Bayes Classifier, Multilayer Perceptron from functions, JRip, PART, OneR from Rules Classifier and Random Forest and J48 from Trees.

III. RESULTS AND DISCUSSION

A total of 8 classification algorithms have been analysed in this study. We evaluate the features with 10-fold cross validation. In the classification process, we perform 10 times for training and testing.

<table>
<thead>
<tr>
<th>Classifier</th>
<th>Time taken to build model</th>
<th>Correctly classified instances</th>
<th>Kappa statistic</th>
<th>Mean absolute error</th>
<th>Root mean squared error</th>
<th>Relative absolute error</th>
</tr>
</thead>
<tbody>
<tr>
<td>J48</td>
<td>0.25</td>
<td>78.24 %</td>
<td>0.628</td>
<td>0.0662</td>
<td>0.182</td>
<td>44.68 %</td>
</tr>
<tr>
<td>Naive Bayes</td>
<td>0.06</td>
<td>77.92 %</td>
<td>0.6229</td>
<td>0.0653</td>
<td>0.1849</td>
<td>44.0 %</td>
</tr>
<tr>
<td>JRIP</td>
<td>9.72</td>
<td>65.22 %</td>
<td>0.1386</td>
<td>0.1362</td>
<td>0.261</td>
<td>91.91 %</td>
</tr>
<tr>
<td>PART</td>
<td>0.8</td>
<td>78.23 %</td>
<td>0.6279</td>
<td>0.0662</td>
<td>0.1819</td>
<td>44.64 %</td>
</tr>
<tr>
<td>Random Forest</td>
<td>14.75</td>
<td>78.23 %</td>
<td>0.628</td>
<td>0.066</td>
<td>0.1817</td>
<td>44.52 %</td>
</tr>
<tr>
<td>MultiLayer Perceptron</td>
<td>26.06</td>
<td>77.93 %</td>
<td>0.6232</td>
<td>0.0669</td>
<td>0.1826</td>
<td>45.15 %</td>
</tr>
<tr>
<td>BayesNet</td>
<td>2.07</td>
<td>77.92 %</td>
<td>0.6229</td>
<td>0.0653</td>
<td>0.1849</td>
<td>44.08 %</td>
</tr>
<tr>
<td>OneR</td>
<td>6.11</td>
<td>72.50 %</td>
<td>0.5247</td>
<td>0.0687</td>
<td>0.2622</td>
<td>46.36 %</td>
</tr>
</tbody>
</table>

The results from TABLE III have been analyzed the classifiers work better. The classifiers J48, Random Forest and PART have performed better in data set (up to %87). Errors and Kappa statistic seem to be same among 3 classifiers and are based on the accuracy of the prediction.

Customer clustering is very important issues in data mining methodologies for customer relationship management (CRM).

To segment customers by Customer Type, Usage Type, Churn Reason, Subscriber Period and Tariff as variables and used K-Means to model the customers into five clusters. To generate roughly the same number of subscribers in each of the seven clusters. Table IV is summarized the clustering results. Simple K-Means method is a common and effective method for clustering.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Active churn</th>
<th>Churn Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>H_B</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Period</td>
<td>6-10</td>
<td>6-10</td>
</tr>
<tr>
<td>Tariff</td>
<td>7</td>
<td>14</td>
</tr>
</tbody>
</table>

From this result, it is possible to generate some customer management strategies. Simple algorithm K means the results can be interpreted as follows.

- Cluster 0: Include %17 of all customers and these customers are active in system 0-5 year period. They use 4.tariff in telecommunication systems for their home.
- Cluster 1: Include %22 of all customers and these customers are active in system 6-10 year period. They use 14.tariff in telecommunication systems for their home.
- Cluster 2: Include %13 of all customers and these customers are churned in system 6-10 year period. They used 1.tariff in telecommunication systems for their business. Churn reason is 1 coded.
- Cluster 3: Include %17 of all customers and these customers are churned in system 6-10 year period. They use 14.tariff in telecommunication systems for their home. Churn reason is 5 coded.
- Cluster 4: Include %14 of all customers and these customers are active in system 16- year period. They use 7.tariff in telecommunication systems for their home.
- Cluster 5: Include %13 of all customers and these customers are active in system 11-15 year period. They use 7.tariff in telecommunication systems for their home.
- Cluster 6: Include %4 of all customers and these customers are churned in system 0-5 year period. They used 3.tariff in telecommunication systems for their business. Churn reason is 2 coded.
IV. CONCLUSIONS

With the strongly development of telecommunication industry, the service providers needs more knowledge of the subscriber. In today’s very hard competitive environment, holding of existing customers has become an enormous challenge. Churn analysis is used to predict of customer behaviours that are most likely to change provided service and to compose special marketing tools for them.

Churn prediction in customer relationship management is critical issues in telecommunication industry. For the purpose of competitive in this industry, service providers must be able to predict probability of churners and take proactive approach to retain existing customers. In this research, we use WEKA data mining algorithms for purpose of different classification techniques and clustering for churn prediction.

This study is inspected determinants of customer churn in the Turkish telecommunications industry service market using a sample of have 498.357 actual and churn customer data. The efficiency and the performance is compared of Naive Bayes and Bayes net from Bayes Classifier, Multilayer Perceptron from functions, JRip, PART, OneR from Rules Classifier and Random Forest and J48 from Trees.

The goal of the paper is define and explain the related factors in active and churn prediction modelling. On the other hand this study aims to cluster the application data with data mining simple k means clustered technique. Classified and clustered that uses for churn prediction in Data Mining.

ACKNOWLEDGMENT

The dataset were obtained one of the biggest telecommunication companies in Kayseri, Turkey.

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A Fast Detection Approach for Road Defects Using Image Processing

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Abstract—Road defect is one of the most important factor for traffic accident. Therefore, this defects should be corrected as soon as possible. It usually occurs cracks, rutting, and potholes in road surface. There are various methods in the literature for the road defect detection. Traditionally these defects is tried to detected by the human eye are performed using image processing in recent years. However, there are deficiencies such as inability of real time application, slow work, and inability to identify with high accuracy in addition to being shortage of studies using image processing.

Aim of this study is defect detection at road by using image processing algorithm with images taken from a camera on a vehicle. In first step of this study, preprocessing is performed by utilizing median filter algorithm. Then, in second step essentially threshold values to detection process are obtained by performing feature extraction with mathematically morphological techniques. In final step whether road defect exist or not, and which level of defect are obtained by being classified in real time. To reveal the accuracy and performance of the proposed approach, comparative results are given by examining images obtained as experimentally.

Keywords—Road defect detection, image processing, morphological operation, decision tree, median filter

I. INTRODUCTION

Roads are the transportation method which is most widely used around the world at the present time. One of the most important causes of accidents on the roads is the road surface faults. The improper operations in the construction phase and the reasons such as pressure caused by heavy vehicles on the roads and weather condition lead to the deformations on the road surfaces over time. These deformations on the road surfaces are called Alligator Cracking, Block cracks, Linear Cracking, Transverse Cracking, Joint Reflection Cracks etc.

The elimination of the road defects is both a big work load and an organizational operation [1]. Today, road defect detection based on the fact that people see these defects. This method prevents the elimination of defects in a short time. Many researchers have proposed different methods about how to detect the defects in a faster way. The features such as being cheap, being fast and and applicable determine the effectiveness of a method [2]. Among these methods, one of the cheapest and fastest method is the algorithms developed using image processing methods.

The crack in the image taken and the contrast between the road are reduced due to the light on the road surface and the changes in weather conditions [3]. It is difficult to perform feature extraction from the road surfaces using image processing methods and to detect feature due to the plurality of the colour changes of the road surfaces [4]. Edge detection methods are very efficient for feature extraction in the other detection problems [5-7]. but performing feature extraction from the road surface is not only edge detection or texture analysis problem [8]. Color changes and noise in received image make difficult to defect detection. In this case, improvement of the image becomes an important duty in order to make an accurate prediction [9]. The road cracks constitute the continuous and darkest region of the image [10]. In the study carried out, the cracked structure was brought to the forefront to improve the image by using a median filter and collecting with an image on which no processing was performed. In the literature, productive results were also obtained by using median filter [12,13] to improve image. In addition to median filter, histogram equalization [8], calculate the threshold value [10], etc. were used for image improving.

Feature extraction defines the relevant shape information in the image [11]. In the literature, edge control [14] and various parameters such as slope, inertia [10] which can be removed through image were used for feature extraction. For instance, Guanqun Bao [12], proposed feature mapping method. This method was based on from vertical histogram and horizontal histogram values.

The usability of road defect detection applications depends on being able to achieve fast and good results. In accordance with this purpose, an attempt to achieve faster and better results was made in the study carried out. If deep cracks on the road are not repaired in a short time, the damage on the road is further increased. Therefore, it is necessary to make the distinction of superficial and deep cracks. In the study carried out, roads were classified as without crack, superficial crack, crocodile cracking, transverse cracking and longitudinal (linear) cracking.

II. PROPOSED METHOD

The proposed method is based on feature extraction and classification through the image obtained by bringing cracked structure into the forefront. The flow chart of the study carried out is presented in Fig. 1.
It is difficult to extract data through the obtained images. Because the received image may be noisy, low contrast etc. The road cracks constitute the continuous and darkest region of the image [10]. The operations required for the detection of the darkest region of the image are obtained more comfortably through the gray scale image. Median filter can be generally used to minimize the angular blurred degradations, soften the flat region and protect the edges [15]. Along with the synchronization algorithm, Median filtering can be used to improve the image contrast with the effects of the impulsive noise and white noise [12, 16]. Median filter is based on the recalculation of all pixel values in the image according to the neighboring pixels. Pre-processing with median filter is often used for preserving edge while removing noise. For the operations to be performed, median filter was used because it gives better results. The crack should be further brought into the forefront in order to find out whether there is a crack in the road images. Operation on rgb image leads to loss of time for road defect detection and it is more difficult than operation on grayscale image. Therefore, it is converted into a gray scale image for next steps as shown in Fig. 2.(b), the blurred image was obtained by applying the median filter. The cracked structure was brought to the forefront by collecting the blurred image and the gray scale image on which no processing was performed. Both fracture parts in the image obtained were brought to the forefront and noisy sections were reduced in the image obtained after the collecting process as shown in Fig. 2.(c).

Morphological operations were carried out in order to correct the sections which were seen as if they were disconnected on the image and to get rid of some undesired defects. The image was transformed into binary image in order to perform mathematical morphological operations and to achieve the cracked structure in a more accurate way.

Mathematical morphological operations are the commonly used methods in the operations of the geometrical structures. Morphological medians are hierarchically represented in similar dimensions among spatial areas [17]. Morphological operations are frequently exposed to scientific thinking and researches like morphological profiles, because Morphological operations are known to be useful for the classification of panchromatic and hyperspectral images with very high spatial resolution [18]. Erosion, dilation, opening and closing are the basic morphological operations. The input image and output image are generated in the same dimension. The pixel values in the processed image calculated by the
neighboring pixels. The mathematical morphological operations of erosion and dilation were applied in order to improve the images of the cracks. In erosion, it is performed by giving the smallest of the neighboring pixels. If the pixel is equal to ‘0’, it remains as is. In dilation, the biggest of the neighboring pixel values is given. If the pixel is equal to ‘1’, it remains as is. The results of morphological operations such as erosion and dilation operations are facilitated the detection of thin fractures in the image.

![Image of Mathematical Morphological Operations](image1.png)

Feature extraction process is based on performing operation over pixels through the image. The total number of pixels in the image is small because the surfaces without cracks are the points which are independent of each other. Therefore, the images below a defined value were accepted as without cracks. In the images with cracks, it was detected that there was a superficial crack if the value which was obtained by the division of the area of the cracked region to the entire area was below a certain value. For crocodile cracking in the images, whether there was crocodile image was detected by calculating the number of objects because more than one objects were obtained. Whether the crack was extended horizontally or vertically was found by detecting its direction. It was accepted horizontal if the obtained value was between -45 and 45, and it was accepted vertical in the other case.

The classification process was carried out with decision trees. Decision tree is performed by the hierarchical fragmentation of the object feature space [19]. A Decision Tree provides open relationship between input features and estimates [20]. Obtained of multiple data in feature extraction has made it’s possible to use decision tree for classification process. So road surface is usually without cracked structure. In the study carried out, whether the road surface is cracked in the root node is detected. If the path is faulty, whether there is a crack in the child node is detected. If the fault is deep crack, whether there is crocodile cracking is detected. If it is not crocodile cracking, whether it is linear or transverse cracking is detected. The operation steps in classification are given in Fig. 5.

![Decision Tree Algorithm](image2.png)

### III. EXPERIMENTAL RESULTS

The study was carried out on a computer with Intel(R) Core(TM) i5 CPU, 2.4 GHz, 3 GB RAM and 64-bit operating system. After the detection and classification algorithm of road surface defects was coded in Matlab on the computer, for the testing operation of the study carried out, the performance of the algorithm was evaluated using the required images which were obtained from both web environment and the camera with CMOS 13.0 MP resolution. The images were obtained by being positioned to be about 1 m above the road surface and 90° to the surface. Some examples of the study carried out and information about how long the operation was performed are given in Table I.

After the image was obtained, it was transformed into gray scale image. The gray scale image was dimensioned and prepared for the mathematical operations to be performed later. The cracked structure was brought to the forefront after blurring the image by median filter and the addition operation. As it is described in the proposed method, the image was transformed into binary image for the mathematical morphological operations after obtaining the cracked structure in the image. Mathematical morphological operations were used to improve the obtained image. An attempt to achieve better results was made by defining two different matrices for the morphological operations performed. In the feature extraction operation, the classification was performed by calculating the total number of pixels obtained through the image, solidity value, total number of objects and the slope of the object for the images consisting of single object. In classification, we found without crack structure because road surface is without cracked in generally. This situation gain time for find cracked structure.

Within the context of the application, to which of the five classes including without crack, superficial, crocodile cracking, linear cracking and transverse cracking the obtained image was belonged was detected. It was applied on various...
types of roads. The performance of the algorithm was evaluated by developing the algorithm developed on Matlab. The system can also detect the cracks about 1 mm in thickness.

The success of the system decreases on poor quality roads and in superficial cracks.

### TABLE I. EXAMPLES OF EXPERIMENTAL RESULTS

<table>
<thead>
<tr>
<th>Image</th>
<th>Crocodile Elapsed time: 0.904033</th>
<th>Transverse cracking Elapsed time: 0.66124</th>
<th>Linear cracking Elapsed time: 0.738105</th>
<th>Transverse cracking Elapsed time: 0.730744</th>
<th>Crocodile Elapsed time: 0.923786</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

**IV. CONCLUSIONS**

The proposed algorithm is a new method used to perform the detection and classification of the road surface defects by image processing methods. In the first stage, operations were performed to bring the cracked structure into the forefront. The cracked structure has further come to the forefront by the mathematical operation performed because it constitutes the darkest part of the image. The roads were divided into five classes as without crack, superficial, crocodile cracking, linear cracking and transverse cracking. For these operations, in feature extraction, they were subjected to classification process according to the total number of pixels, solidity value, the number of objects in the image and the continuation angles of the cracks. The decision trees were used for the classification process.

The proposed method can also be used for the detection of very fine cracks. However, its performance decreases in the color changes that occur due to various reasons on the roads. The image taken by the camera should be obtained under appropriate lighting conditions in order to increase the efficiency of the algorithm.

The algorithm developed performs the classification operation between 0.940736 - 0.632034 sec. It has an average success rate of 80%. This also indicates that it is a system that can be used in real life.

### REFERENCES


A Vision Based Detection Approach for Level Crossing and Switch in Railway

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Abstract—Railroad transportation is considered one of the safest means of transportation. Important components of this transportation are tracks, level crossing, turnout, and so forth. Detection of these component is critical for realizing centralized supervision, comprehensive evaluation, and accident prevention. Safety of railroad can be developed using intelligent systems which supply additional information about the exact location of the train, its speed and upcoming obstacles. Level crossings in railroad are significant safety points. Because there is the risk of collisions between motor vehicles and trains. Therefore it is necessary first to detection level crossings for detection of obstacles in level crossings. In this paper a vision based approach is presented that detects to level crossings and turnouts in railway. In the images of a camera that observes the area in front of a railroad vehicle the rail tracks are detected in real-time. These images are converted to HSV color format in first step of the proposed method. Then image normalization and gradient computing are performed. In the next step, the effect of illumination on the appearance of the image is removed with ratio of gradient magnitude and gradient the average of the gradients of all pixels in the image. Then to suppress the effects of pixels with large gradients, and noisy pixels, during illumination normalization, weights are calculated. In the next step the computation of the weighted average of V values of the pixels inside the rectangular windows with varied sizes is time consuming. Therefore to speed up the computation, Integral image which is an elegant technique for efficiently carrying out an averaging operation is applied to result image in the final step. In this way turnout detection is realized. While preprocessing, feature extraction, and image processing techniques is used in level crossing detection process.

Index Terms—Railroad Switch Detection; Level Crossing Detection; Integral Image; Image Processing; Image Normalization

I. INTRODUCTION

The importance of railway transportation has been increasing in the world. As the railway traffic are developing at a dramatically speed all over the world, the safety and comfort of the railway system are paid more attention than ever before. It is required that the railways are examined in more detail with the enhanced railroad technology. Trains are considered one of the safest means of transportation. Accidents still often happen due to driver’s tiredness, bad weather conditions or other factors. Safety can be enhanced using intelligent systems that supply additional information about the exact location of the train, its speed and upcoming obstacles [1]. Manual inspection of rails is slow and contact inspection methods harm the rails, rail analysis is performed with machine vision via non-contact, high accuracy and high speed methods [2]. Besides, manual inspection is expensive and cause to temporarily disable of railway [3].

Railway turnout systems are one of the most critical pieces of equipment in railway infrastructure. A turnout is used to transfer vehicles from one track to another track. As an important part of railway system, the turnouts have a strong relation to the comfort of the railway vehicles and severe turnout defects can lead to accidents [4]. Therefore, it is important to detect turnout defects timely. Switch is one of the three outdoor railway equipment [5]. It has many characteristics such as large quantity, complex structure, short using life, limiting the train speed, low driving safety, big investment for maintenance etc. [5]. It is also one of the three major weaknesses in rail.

To locate railway vehicles exact and reliably in railroad network, collision avoidance systems are required. In this systems it is vital to determine the direction a railroad vehicle turns at switches. Most of common driver assistant systems work on unstructured environments for detection of obstacles [6]. These environments include many non-planar surfaces which pose a big challenge for vision systems [6]. Alike problems exist for railroad environments which frequently contain complex shapes and surfaces like hills and vegetation along railroad tracks [6]. In railroad transportation, main task of train driver is carefully to focus on rail track. Therefore vision area of train driver is area between two rails in front of train and right and left sides of these rails.

Three important component of railway can be expressed as rails, switches and level crossings. Detection of switches and level crossings can be seen as possible accidents prevention tool and driver assistance system. The developed methods related with based contactless image processing switch detection are available in literature. Li et al. [7], enhanced line detection method for railway switch machine monitoring system. This method was based on image processing techniques. It was used to Canny edge detection, Zhang Suen Thinning method to reduce the thickness of the edges and Probabilistic Hough Transform to detect the lines in this study
Espino et al. [1] offered a method that detects railway track and turnout. And this method was not based on an empirical threshold. Railway track extraction was not based on an edge detection using the width of the rolling pads. This edge detection scheme was then used as an input to the RANSAC algorithm to determine the model of the rails. The turnout detection scheme was based on the Histogram of Oriented Gradient (HOG) and Template Matching (TM) [1]. To detect railway turnout, Support Vector Machine (SVM) was also used. Qi et al. [8] presented a novel railway tracks detection and turnouts recognition method by using HOG (Histogram of Oriented Gradients) features. Firstly, this method computes HOG features and defines integral images, and then extracts railway tracks by region-growing algorithm [8]. By recognizing the open direction of switch, this method finds path where the train will travel [8].

Wohlfeil [9] recommended a vision-based method that provides to determine the direction a railroad vehicle turns at switches. A camera observed area in front of railroad vehicle and images of this area were used to detect rail tracks in real-time. Switches were detected by tracking rail tracks in these images. It was shown that the followed track can be determined at branching switches [9]. Kaleli and Akgun [10] offered an algorithm to extract railroad track area in front of the train by utilizing Dynamic Programming. They utilized dynamic programming to compute the optimal path which gives the minimum cost to extract the railroad track space. This algorithm extracted the left and right rails through utilizing dynamic programming simultaneously.

Espino and Stanciulescu [11] improved a vision based algorithm which detects railway track and turnout and classifies turnout. In this algorithm, railway track detection was performed with edge detection using the width of rolling pads [11]. Then this edge detection scheme was used as an input to the RANSAC algorithm to determine model of rails knowing their gauge. Turnout detection process was based on Histogram of Oriented Gradient (HOG) and Template Matching (TM) in this study. The turnout classification process was based on Histogram of Oriented Gradient (HOG) in this study [11]. Ross [12] proposed the utilization of a monofocal video camera to enhance the localization quality. Ross’s algorithm estimated the track recursively in camera images.

II. RAILROAD SWITCHES AND LEVEL CROSSINGS

Switches, also called turnouts or points, are an important part of railroad. This component enables to orient from one track to another. Switches are a fundamental part of the railway infrastructure, given that they enable the creation of a real network. Turnouts are not only placed in the infrastructure to connect different lines, but also to connect parallel tracks of the same line [13]. So, this process give flexibility to track. The operational effect reasoned by a case on track is directly related to the number of crossover in the line [13]. Moreover turnouts offer a singular point in the track. When compared to plain track, switches have higher track toughness considering that they are supplied with altered sleepers dimensions and arrangements, additional rail elements, etc. Besides, according to adjacent rail track, the conditions of the wheel-rail interface change significantly given the rail geometry interruption of switch [13]. Components on the railway line should be monitored at regular intervals to ensure continuous transport security [14].

Switches must be kept in good condition in order to guarantee an enough running of the train through switch. If this situation is not properly maintained, the wheel-rail interface will be negatively affected. Because of safety and operational issues, switches are intensively examined and protected. In spite of high investment on maintenance, switches have a lesser existence than plain track be considering that they suffer higher stress. The switch consists of the pair of linked rails. There are a number of standard layouts or types of turnouts [15]. These types are Left Hand Turnout, Y Turnout, Diamond Crossing, 3-Way Turnout, Single Slip and Double Slip, as shown in following diagrams.

The term level crossing is also called are railroad crossing, railway crossing, road through railroad, train crossing or grade crossing. The level crossing is a crossing on one level of a railway line by a road, path, or another railroad [16]. Level crossings are high risk areas where rail traffic crosses paths with road and pedestrian traffic at the same level. In many countries, level crossings on less important roads and railway lines are often open or uncontrolled [16]. An example of level crossing is shown in Fig. 8.
III. THE PROPOSED METHOD

The rail tracks, switches and level crossings are vital components in railway. To be safety transportation in railroad, these components should be controlled and be examined whether defects or not. Determination of these components with contactless image processing techniques provides additional information such as exact location of train, its speed and upcoming obstacles.

A contactless vision based image processing algorithm is recommended in order to detect rail track, switch and level crossing. Block diagram of switch detection algorithm is as shown in Fig. 8. Steps of this algorithm are respectively acquiring the railway images, determining the region of interest with ROI segmentation, rail track extraction, and determination of switch crossing. Acquiring the images, first of these steps, is process of taking images from the camera that is placed on top of the train. Determining the region of interest is performed with ROI segmentation. Region of interest consists of rail track area in front of train. Using ROI segmentation has led to easier detection of the track. The next step is rail track extraction. Result image of this extraction process includes only rail track and small amount of noisy pixels. Switches in image are detected in final step.

Figure 8. Block diagram of switch detection algorithm

A. ROI Segmentation Method

The flowchart of ROI segmentation algorithm is shown in Fig. 9. To extract region of interest area, we compute to the railroad vanishing point \( \mathbf{p} \) and track width parameter \( W_{\text{max}} \) from an input image. Rail tracks are aligned parallel to each other and their width decrease linearly in the image from bottom to up. Vanishing point term refers to the intersection of the track lines defined as in Liang [18]. It is firstly performed color conversion from RGB to HSV color space in this algorithm. HSV color space consists of 3 channels. These channels are Hue (H), Saturation (S), and Value (V). Hue channel defines the dominant wavelength of the color such as green, blue, yellow, and etc. And this channel has a value between 0-360 angular. Saturation channel identifies the vividness of the color. High saturation reasons to vivid colors and low saturation ensures that the color approaches to shades of gray. While value channel defines white rate of within color. So it identifies the bright of color. In this study, ROI segmentation steps are performed on V channel image.

In gradient computing step, the gradient of input image is computed by using Sobel operator and thereby gradient magnitude image \( \text{Gradient}(i,j) \) is obtained. Then a given threshold value is applied to the bottom 1/5 of the gradient image due to the fact that this part of the image includes sufficient information to extract the features. Furthermore rail tracks are straight and their gradient magnitudes are high in the bottom of the image. This threshold process eliminates the points that have lower gradient magnitude from the threshold value \( T \). In the next step, a binary image \( \text{Binary}(i,j) \) is constituted from gradient image \( \text{Gradient}(i,j) \) by Equation 1.

\[
\text{Binary}(i,j) = \begin{cases} 
1 & \text{if Gradient}(i,j) > T \\
0 & \text{otherwise}
\end{cases}
\]

In the next step, Hough transform is carried out to binary image \( \text{Binary}(i,j) \) in order to detect rail lines. Hough transform returns lines that have different lengths. Hough transform is very helpful in order to detect straight lines. Lines returned include their end-point coordinates without line length information. The length of a straight line between its two end points \((x_1,y_1)\) and \((x_2,y_2)\) is computed by Equation 2.

\[
\text{length} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}
\]

This operation specifies many lines including rail track lines. But the lines expect for rail track lines are also available. Thus we extract the rail lines which are the longest lines on the left and right. Then the longest line on the left and right can be founded by calculating line lengths by Equation 3.

\[
y = mx + c
\]

After rail track lines are detected by using Hough transform [19, 20], the intersection of two straight rail lines in the image can be computed. To compute vanishing point, common form of a linear equation can be used. This equation is described in Equation 3. This equation is slope-intercept form, where \( m \) is the slope and \( c \) is the y-intercept of the line. The slope equation of a line which passes through two different points \( P_1(x_1,y_1) \) and \( P_2(x_2,y_2) \). This equation is shown in Equation 4.

\[
m = (y_2 - y_1)/(x_2 - x_1)
\]

The y intercept of a line which passes through two different points \( P_1(x_1,y_1) \) and \( P_2(x_2,y_2) \). This equation is shown in Equation 5.

\[
c = (x_2y_1 - x_1y_2)/(x_2 - x_1)
\]

The y coordinate of vanishing point \( p \) is computed by Equation 6.
\begin{equation}
\text{Point}_y = \frac{(m_1 c_2 - m_2 c_1)}{(m_1 - m_2)} \quad (6)
\end{equation}

In Equation 6, Point\(_y\) is the \(y\) coordinate of the intersection of lines. \(W_{max}\) can be computed by subtracting \(x\) coordinates of the rail lines at bottom of the image. So region of interest area in image is detected with \(W_{max}\) and Point\(_y\) obtained. And then this area is extracted from image by cropping. So ROI process facilitates in order to detect of rail track in image.

B. Rail Track Extraction Method

To determine of rail track in ROI area extracted from image, the flowchart of algorithm used is shown in Fig. 10. The rail track extraction algorithm consists of a few steps. These steps are respectively HSV color transform [37], V channel normalization, gradient image computing, and Integral image computing. V channel normalization is firstly applied within a range between 0 and 255, because RGB-HSV color transform was previously applied to ROI image in an earlier chapter. \(x\) and \(y\) axis gradients of image are computed. In the last step Integral image is computed and rail track image is extracted. And finally rail track is extracted from rail image by applying some morphological operations.

In the normalization step range of pixel values is exchanged. Normalization is expressed as histogram stretching or contrast stretching. The normalization returns a grayscale image and returns new values within range newMin and newMax with intensity values between Min and Max. Linear normalization of grayscale digital image is performed according to following formulation [21].

\begin{equation}
I_N = (I - \text{Min}) \times \frac{\text{newMax} - \text{newMin}}{\text{Max} - \text{Min}} + \text{newMin} \quad (7)
\end{equation}

In the Equation 7, \(I_N\) is normalization image, Min is minimum value of pixels, Max is maximum value of pixels, newMin is minimum value of new range values, and newMax is maximum value of new range values.

Gradient image is calculated using Sobel operator. The obtained gradient image is used to get Integral image. Gradient image is obtained with Equation 8 and Integral image is obtained with Equation 9.

\[ G_x = I_N \times 2 \quad 0 \quad -2 \]
\[ 1 \quad 0 \quad -1 \]
\[ G_y = I_N \times 0 \quad 0 \quad 0 \]
\[ 1 \quad 2 \quad 1 \]
\[ 0 \quad 0 \quad 0 \]
\[ -1 \quad -2 \quad -1 \] \quad (8)

\[ I_{II}(i,j) = \begin{cases} 
I_n(i,j) & \text{if } i = 0 \text{ or } j = 0 \\
I_{II}(i-1,j) + I_{II}(i,j-1) - I_{II}(i-1,j-1) + I_n(i,j) & \text{otherwise} 
\end{cases} \quad (9)\]

In the Equation 8, \(G_x\) is x-axis gradient image and \(G_y\) is y-axis gradient image. \(I_{II}(i,j)\) is integral image in the Equation 9.

C. Switch Detection Method

Tracking algorithm is used to detect whether there are switch crossings in image extracted rail track. To identify connection points of rail track in the rail image, tracking algorithm is applied to the rail image. Visual tracking is hot topic in the research areas of computer vision and multimedia processing [22]. In the past decades, there have been diverse visual tracking algorithms proposed for object tracking in video sequences in tracking conditions such as strong occlusion, complex background, quick movement, etc. [23, 24].

The object tracking is performed in two stages. First, the algorithm must seek in image for a known object of interest. The other, the algorithm can search the whole image again for the object movement [25]. In the field of Unmanned Aerial Vehicle (UAV) there are a few attempts on tracking landing pad. Most of them include of finding an ellipse using thresholding technique couple with finding connected components [26, 27, 28].

The proposed switch detection algorithm is shown in Fig. 11. The connection points of rail track is detected by using tracking algorithm in order to determine switches. Hence, rail object is followed by analyzing image from the bottom-up and connection points have been founded. With number and location of these points, direction of switch crossing is determined. Detected connected points are shown in Fig. 12 as an example.

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Switch Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(G \leftarrow \text{Rail track image})</td>
</tr>
<tr>
<td>2</td>
<td>(T \leftarrow \text{Processed rail track image})</td>
</tr>
<tr>
<td>3</td>
<td>(k \leftarrow \text{Connection point array of rail track})</td>
</tr>
<tr>
<td>4</td>
<td>(R, C \leftarrow \text{The number of row and columns})</td>
</tr>
<tr>
<td>5</td>
<td>For all (i) such that (i &lt; C)</td>
</tr>
<tr>
<td>6</td>
<td>For all (j) such that (j &lt; R)</td>
</tr>
<tr>
<td>7</td>
<td>(T(i,j) \leftarrow \text{Being applied Tracking algorithm to } G(i,j))</td>
</tr>
<tr>
<td>8</td>
<td>(k \leftarrow \text{Connection points being detected from } T(i,j))</td>
</tr>
<tr>
<td>9</td>
<td>endFor</td>
</tr>
<tr>
<td>10</td>
<td>endFor</td>
</tr>
</tbody>
</table>

Figure 11. The algorithm of switch detection
D. Level-Crossing Detection Method

Level crossings that are located between the rails in a vertical position are horizontal position. To determine level crossings some of image processing techniques such as preprocessing, feature extraction, Hough transform, etc. are applied to image. The pseudo code of level crossing detection algorithm is shown in Fig. 13.

In the first step of level crossing detection algorithm, the image in RGB color space is convert to XYZ color space. XYZ color space is expressed such that all visible colors can be defined using only positive values. And the Y value is luminance [29]. Red, green, and blue values are to be unwanted for creating a standardized color model that is suitable for all devices [29]. Because of this reason XYZ is used a mathematical formula to convert the RGB data. X, Y, and Z values can be obtained as shown in the following Equation 10.

\[
\begin{bmatrix}
X \\
Y \\
Z
\end{bmatrix} =
\begin{bmatrix}
0.41 & 0.35 & 0.18 \\
0.21 & 0.71 & 0.07 \\
0.01 & 0.11 & 0.95
\end{bmatrix}
\begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\]  (10)

In the next step of level crossing detection algorithm, Y channel image is obtained and this channel image is utilized in later stages of proposed algorithm. The reason for using this channel in later stages of the proposed algorithm, is to express luminance value in image. Then, gradient magnitude and x and y direction gradients of this image are calculated [30, 31, 32].

Algorithm: Level Crossing Detection

1. \( L \leftarrow \) Level crossing image
2. \( XYZ\_Image \leftarrow \) Obtained XYZ image
3. \( Y \leftarrow \) Obtained Y channel image
4. \( G \leftarrow \) Obtained gradient image
5. \( k \leftarrow \) The number of detected line on image
6. \( R, C \leftarrow \) The number of row and columns
7. For all i such that i≤C
8.   For all j such that j≤R
9.       \( XYZ\_Image\,(i,j) \leftarrow \) Converting \( L(i,j) \) from RGB to XYZ
10.      \( Y(i,j) \leftarrow \) Getting Y channel image
11.     \( G(i,j) \leftarrow \) Applying edge detection method to \( G(i,j) \)
12.   \( k \leftarrow \) Finding lines in \( G(i,j) \) image with Hough transform
13. endFor
14. endFor

In the next step, edge detection process is made on image. Prewitt edge detection algorithm is used to this. Prewitt mask is a discrete differentiation operator. This operator uses two 3×3 masks for calculating approximate derivative values in horizontal and vertical directions [32, 33]. Prewitt masks are shown in Fig. 14.

![Prewitt masks](image)

(a) X direction mask  (b) Y direction mask

Figure 14. Prewitt masks [33, 34, 35]

The Prewitt edge detection mask gives equal weightage to all pixels when averaging [35]. As seen in the mask the coefficients in the matrix kernel are all 1 [35]. The key idea is that of central differences. This mask when convolved with an image, it performs a two dimensional spatial gradient [35].

After done edge detection step, two different images are obtained by applying two filter which 0 and 90 degrees in terms of size. And difference process is performed by subtracting these images obtained from each other. In this way the level crossing that is horizontal position in the image, has become sharper. Then Hough transform is applied to detect line in image. The Hough transform is utilized in order to determine the straight lines and parametric curves in an image [36]. The pseudo code of Hough transform algorithm is shown in Fig. 15.

Figure 15. The algorithm of Hough transform [36]

IV. EXPERIMENTAL RESULTS

A computer which has Intel (R) Core (TM) i7-2400 M CPU, 2.5 GHz, 6.00 GB RAM under Windows seven 64 bits is used to perform the proposed method. The proposed methods are written in Matlab R2014b. In this study, switch and level crossing detection in railway are developed through using contactless image processing techniques.

ROI segmentation is made in the proposed algorithm to detect region of interest in the image i.e. rail track area. Images which are given to proposed ROI method as input and results of the proposed ROI method are respectively shown in Fig. 16.
Level crossing detection has been made in the railway image. And edge detection algorithms such as Sobel, Canny, Roberts, and Prewitt have been tried to detect level crossing. It has been observed that Prewitt edge detection algorithm has produced better results than other edge detection algorithms. Images which are given to proposed level crossing detection method as input and results of the proposed level crossing detection method are respectively shown in Fig. 19 and Fig. 20. Experimental result of level crossing detection algorithm is shown in Table III.

![Figure 19. An railway input image of level crossing detection method](Image 343x449 to 535x467)

![Figure 20. Detected level crossing image](Image 64x612 to 225x742)

<table>
<thead>
<tr>
<th>Image Size</th>
<th>Elapsed Time (Sec)</th>
<th>Accuracy Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>230 x 380 pixels</td>
<td>0.42</td>
<td>87</td>
</tr>
</tbody>
</table>

### V. CONCLUSIONS

An algorithm based contactless image processing has been suggested to detect switches and level crossings in railway. The switch detection has been performed by using ROI segmentation, rail track extraction and switch detection algorithm. With being performed ROI segmentation, both rail track has been extracted more easily and accurate rate of switch detection has been increased. So expressed step is very important for switch detection process. And also image used for switch detection is free of foreign objects such as trees, buildings, etc. by applying this step. To perform ROI segmentation, the image has been converted to HSV color space. V channel of this image has been used during the proposed method. With used this channel image, rail object could appear in clearer way and that has facilitated other image processing steps. Hough transform has been used to detect rail track line. The use of Hough transform has played an important role in determining the rail line. The Integral Image has simplified rail track detection. In the switch detection step, connection points of switches have been determined with tracking algorithm. The proposed methods have been written in Matlab 2014b. Average elapsed time of the proposed switch detection method has been 0.40 seconds and accuracy rate of the proposed switch detection method has been 89.66 %. Thanks to level crossing detection, while train travel it can be found that whether there are obstacles on level crossing. And thus train accidents can be prevented. With detection of level

![Figure 16. (a) Example railway input image (b) output image for ROI segmentation method](Image 64x612 to 225x742)

![Figure 17. (a) Input and (b) output images of Rail Track Extraction](Image 104x218 to 159x319)

<table>
<thead>
<tr>
<th>Image Size</th>
<th>Elapsed Time (Sec)</th>
<th>Accuracy Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>280 x 230 pixels</td>
<td>0.24</td>
<td>92</td>
</tr>
<tr>
<td>65 x 145 pixels</td>
<td>0.12</td>
<td>90</td>
</tr>
</tbody>
</table>

As seen in Fig. 16, with ROI segmentation process railway image is reduced to rail track image. And thus rail track has been identified more easily. In addition to this, success rate of rail track detection has been increased. Experimental result of ROI segmentation is shown in Table I.

Rail track extraction is performed in the proposed algorithm to extract rail track in the image. Rail track is identified in the image that is taken from ROI segmentation algorithm as an output image. Input and output images of Rail Track Extraction algorithm are given in Fig.17. And in addition to this, experimental result of Rail Track Extraction algorithm is shown in Table II.

As seen in Fig. 17, white pixels in the output image have been represented as rail track. Then rail track is extracted by applying mathematical morphological operations. After the rail track detection has been done, switch crossing has been identified with switch detection process. To detect switches elapsed time is 0.08 seconds and success rate of switch detection algorithm is 87%.

![Figure 20. Detected level crossing image](Image 64x612 to 225x742)
ACKNOWLEDGMENT

This work has been supported by TUBITAK (The Scientific and Technological Research Council of Turkey).

Crossing, obstacle detection process can be done in the image. Average elapsed time of the proposed level crossing detection method has been 0.45 seconds and accuracy rate of the proposed level crossing detection method has been 87%.


A Hybrid Approach for Indoor Positioning

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Abstract—Positioning systems have wide range of applications with the developing technology. Global Positioning Systems (GPS) is an efficient solution for outdoor applications but it gives poor accuracy in indoor environment. And, various methods are proposed in the literature such as geometric-based, WiFi fingerprint-based, etc. In this study, a hybrid approach that uses both clustering and classification is developed for WiFi fingerprint-based. Information gain based feature selection method is used for selection of the most appropriate features from the WiFi fingerprint dataset in the initial step of this approach. Then, Expectation Maximization (EM) algorithm is applied for clustering purpose. Then, decision tree algorithm is used as a classification task for each cluster. Experimental results indicate that applied algorithms lead to a substantial improvement on localization accuracy.

Keywords—WiFi fingerprint-based, indoor positioning, access point selection, clustering, classification, feature selection, expectation maximization, decision tree, received signal strength, WLAN.

I. INTRODUCTION

Positioning systems are becoming very important with the developing technology. These systems are used to determine the position of the mobile device and it is used by location-based services for navigating, or tracking etc. They are classified as outdoor and indoor positioning systems. Global Positioning System (GPS) is used for outdoor in our daily life. But, it cannot be used for indoor environment due to lack of GPS signals including multipath and signal blockage [1]. Therefore, different kinds of indoor positioning systems (IPSS) have been developed. WiFi-based indoor positioning systems have become an attractive solution in indoor area since WiFi access points (APs) can be found widely in indoor buildings such as airports, shopping malls, or office buildings, etc. WiFi-based indoor positioning is an inexpensive solution because they have not need any additional installation cost [2].

Fingerprinting technique is the most accurate technique that is based on Received Signal Strength (RSS) in WiFi-based indoor positioning systems [3]. In this technique, the RSS obtained from WiFi APs is used to determine the position of a mobile device. It contains two phases named as offline and online phases. In offline phase, RSS values are collected at known reference points (RP) in the experimental area and then are used to construct radio map. The dimension of the radio map is grown while including all the detectable APs in the region. But all these APs are not contributed positively to the accuracy of position. Therefore, the redundant APs will be removed from the radio map, since they increase the computational cost and also cause deterioration in the accuracy of position. For this purpose, the redundant APs are eliminated using feature selection methods. During the online phase, the radio map is used to estimate the location of a mobile device using a new RSS measurement using machine learning algorithms such as Decision Tree (DT), K-nearest neighbour (KNN), or Expectation Maximization (EM) etc. [4]

In this study, a hybrid approach that combines clustering and classification algorithms is applied. InfoGain based feature selection is firstly used to removed redundant APs in the radio map. Then, EM clustering algorithm is utilized to divide radio map into distinct groups or clusters. Finally, after assigning each test data to correct cluster, DT classifier algorithm is used as a classification task. In the experiments, DT and applied hybrid approach is compared in terms of positioning accuracy. In the experiments, WEKA open source machine learning toolbox and RFKON database [5] are used.

The paper is organized as the follows. Related works in literature for fingerprinting based indoor positioning is given in section 2. Section 3 focuses on applied hybrid approach introducing the algorithms using in this approach. Experimental area is given in section 4. Test results for proposed algorithm are given in section 5. As a result of this paper, conclusion part summarizes all written things in the paper with a short paragraph including future works in section 6.

II. RELATED WORKS

A large number of studies that adopt fingerprinting as the position estimation method are proposed in the literature. Fingerprint-based positioning algorithms can be categorized into two groups: deterministic algorithms [2, 6-8] and probabilistic algorithms [9-13].

Deterministic algorithms are used to find the minimum signal distance between the newly measured RSS vector and pre-measured fingerprints which are vectors of RSSs from detectable APs in the region (radio map). Each fingerprint in the radio map is associated with a known RP. In [2], KNN is used to estimate the position of a mobile WiFi-enabled device. A feature scaling based KNN (FS-kNN) algorithm is proposed in [6] to improve localization accuracy. In FS-kNN, different weights are assigned to signal differences at different RSS levels when estimating the similarity between two RSS vector. Artificial neural network (ANN) classifier is utilized to classify link quality patterns for each location in [7]. In [8], DT algorithm is used as the classification algorithm.
In probabilistic algorithms, the probability of the mobile device position to be each reference point is calculated and then maximum probability is returned as a mobile device position. In [9], particle filter, a Bayesian based method, is employed. Observed signal strengths are obtained using Bayesian inference in [10] and the estimated position is determined as the highest probability in the resulting distribution. An extended Kalman filter based approach is presented in [11], where the intra cell position of a cellular device is estimated using RSS readings from base stations. This estimate, movement pattern data and velocity vectors are combined in order to predict the next cell crossing. In [12], a Bayesian filter based approach is proposed. In this study, a posterior probability distribution over the target’s location is obtained by inverting Bayesian belief network. In [13], subset of the strongest APs is considered instead of all APs and target location is predicted using Bayesian estimate.

There are also various algorithms are proposed in the literature to reduce the computational cost by eliminating redundant APs in the radio map. In [14], according to strength of the signal a weight is assigned to each AP and then the APs with minimum weights are dropped from each fingerprint. Various AP significance measures such as average RSS, entropy, variance, maximum RSS are examined in [15]. Fast Orthogonal Search (FOS) and modified FOS (mFOS) algorithms are implemented in [16] in order to reduce the dimensionality of the radio map in an IPS.

III. APPLIED HYBRID APPROACH

In this study, a hybrid approach that combines clustering and classification algorithms is applied. Information gain based feature selection is firstly used to remove redundant APs in the radio map. Then, EM clustering algorithm is utilized to divide radio map into distinct groups or clusters. Finally, after assigning each test data to correct cluster, DT classifier algorithm is used as a classification task. These algorithms are described in the following subsections.

A. InfoGain-based Feature Selection

Information gain is the most commonly used feature selection method in the machine learning field that is based on the entropy [16]. Information gain of each feature is calculated using Eq. (1).

\[
\text{InfoGain}(f) = \sum_{c \in C} p(c) \log \left( \frac{1}{p(c)} \right) + \sum_{f \in F} p(f) \sum_{c \in C} p(c|f) \log p(c|f)
\]

where \( f \) is the feature and \( c \) is the class.

B. Expectation Maximization (EM) Clustering Algorithm

Clustering algorithms assign similar data to same cluster without the prior knowledge about the data’s characteristics. Since the data’s labels’ are not known, these algorithms are also called as unsupervised learning algorithms [17]. EM algorithm is a clustering algorithm that assigns data to particular clusters by computing one or more probability distributions. It then maximizes the overall probability of the data belonging to a certain cluster [18]. EM algorithm consists of two steps: determination of expectation and maximization of expectation iteratively. In this study, EM algorithm in WEKA is used for clustering purpose.

C. Decision Tree Classifier Algorithm

Decision Tree predicts an output by tracking the decisions in the tree from the root node down to a leaf node according to the outcome of the tests along the path [19]. In this study, C4.5 that is a benchmark tree (J48 in WEKA) is applied in the classification step.

IV. EXPERIMENT

Data were collected to construct our database for Eskisehir Osmangazi University Teknopark. It has two floors of area of 800m². This area was broken into grid squares (each of size 2.4m × 2.4m). We collect the data from the first floor of Teknopark and the center of each grid square was noted as seen in Fig. 1.

![Fig. 1 Experimental environment of floor 1.](image)

As seen in Fig. 1, red stars represent the reference points that are used for collecting sensor values from the APs and red squares represent sensor nodes in the test area. The database and the experimental area are briefly described in [5]. There are 5 sensor nodes and 20 reference points in the original RFKON database. And, WiFi RSS values of 80 are obtained from per reference point (RP). There are 1600 instances in the train data and 1600 instances in the test data. In experiments, we use mobile-based WiFi RFKON database that is obtained using Sony Xperia mobile device.

V. EXPERIMENTAL RESULTS

In experiments, we first apply “InfoGainAttributeEval” function in WEKA to determine the number of most important APs using both train and test data with Decision Tree classifier. These results are given in Fig. 2.
In the clustering phase, EM algorithm is applied. In experiment, different number of clusters are tried to select the best number of clusters. 5 clusters give best accuracy results after selecting 8 APs using Information gain based feature selection algorithm. This is an important improvement of reducing computational time.

In the clustering phase, EM algorithm is applied. As seen in Fig. 2, we obtain best accuracy results after selecting 8 APs using Information gain based feature selection algorithm. This is an important improvement of reducing computational time.

The accuracy result of DT classifier using all APs in the database is 42.25. However, we obtain nearly same result (42.375) when we select 8 APs after applying Information gain based feature selection algorithm. As a result of Table II, the hybrid approach increases the accuracy (66.42) about 25 percent using 8 APs. To demonstrate the applied hybrid algorithm improvement on the decision tree size, Table III is constructed.

VI. CONCLUSIONS

In this study, a hybrid approach that uses both clustering and classification is applied in WiFi fingerprint-based method. Redundant APs are eliminated from the WiFi fingerprint dataset using Information gain based feature selection method in the initial step of this hybrid approach. In the clustering step, Expectation Maximization (EM) algorithm is applied. In the last step named as classification step, decision tree models are constructed for each cluster. Experimental results indicate that applied algorithms lead to a substantial improvement on reduced the total computational time of classification process while increasing the accuracy results. The comparison of the applied hybrid algorithm with DT algorithm is given in Table II.

There are 19 APs in the database before applying Information gain based feature selection algorithm. As seen in Fig. 2, we obtain best accuracy results after selecting 8 APs using Information gain based feature selection algorithm. This is an important improvement of reducing computational time.

In the clustering phase, EM algorithm is applied. In experiment, different number of clusters are tried to select the best number of clusters. 5 clusters give best accuracy results among the attempted cluster numbers. The RPs are numbered as seen in Fig. 3 to illustrate the cluster assignments clearly.

![Fig. 2 Number of APs determination using both train and test database with InfoGainAttributeEval.](image)

![Fig. 3 The representation of each reference point.](image)

Each RP that illustrated with numbers in Fig. 3 is assigned to a cluster using EM algorithm as seen in Table I.

<table>
<thead>
<tr>
<th>Cluster Name</th>
<th>RP number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cluster0</td>
<td>7, 8, 9, 10</td>
</tr>
<tr>
<td>Cluster1</td>
<td>19, 20</td>
</tr>
<tr>
<td>Cluster2</td>
<td>11, 12, 13</td>
</tr>
<tr>
<td>Cluster3</td>
<td>14, 15, 16, 17, 18</td>
</tr>
<tr>
<td>Cluster4</td>
<td>1, 2, 3, 4, 5, 6</td>
</tr>
</tbody>
</table>

Finally, DT classifier is applied for each cluster. In this step, cluster specific DT models are constructed. This step is

![Cluster specific DT models are constructed. This step is](image)
localization accuracy. In addition to this, by the help of the clustering phase of the applied approach and constructing cluster specific DT models reduce the size of the tree significantly.

In a future work, different clustering and classification algorithms will be evaluated in a hybrid approach to get better results in terms of accuracy and computational time.

ACKNOWLEDGMENT

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A New Real Time Control Approach for Time Efficiency in Group Elevator Control System

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Abstract— In parallel with the increase seen in the number of high-rise buildings, vertical transport systems are progressing. One of the results of this progress is the emergence of group elevator systems and their primary aim is to transport its passengers to the target floor the fastest way possible. Studies on this field are generally simulation and optimization based and they have an aim of minimizing the passengers’ waiting and traveling periods. In this study, a real time group elevator experimental setup was created and an optimization algorithm was applied on the setup. Genetic algorithm was chosen as optimization algorithm and this method was tested in an elevator prototype of 10 floors and 5 cabins. The results obtained revealed efficiency, performance and accuracy of proposed method.

Keywords— group elevator systems, optimization, genetic algorithm, average waiting time, real time control

I. INTRODUCTION

Elevator systems are of utmost importance in our daily lives. These systems are used in nearly all fields and they provide ease especially in vertical transport [1, 2]. In addition to this, when we take rising number of high-rise buildings of today’s world into account, importance of elevator systems increases [3].

In parallel with increasing number of floors in buildings, the population in the buildings also increases and single cabin elevator systems fail to meet the needs of this population [4-6]. Group elevator systems, which have emerged for satisfying this needs, are seen in many buildings and are in active use today. In general sense, group elevator systems are active usage of two or more elevator systems in the same building. Main aim of these systems is to ensure that people’s average waiting and traveling period is reduced [5-7].

In one of the studies in line with these objectives, group elevator systems are optimized using genetic algorithms. In the study, a system of 20 floors and 4 cabins were created and reducing people’s average waiting and traveling period is aimed. Directional calls were used and these calls were previously uploaded into the system. Obtained simulation results show efficiency of the proposed approach [8]. In another study on the same subject, hybrid optimization technique was proposed. In the study in which particle batch optimization and simulated annealing algorithms are used and a system of 16 floors and 4 cabins was preferred. Average waiting period, long waiting percent and process time was taken into account in the study. Proposed approach overcome the deficiencies of particle batch optimization algorithm and offered a new solution for timing group elevator systems [9].

In another study on group elevator systems, three different optimization techniques were used for process of timing. Genetic algorithm, artificial immune algorithm and DNA algorithm were used in this study and an estimation algorithm was proposed. In simulation processes, a 20 floor and 5 cabin system was considered and approximately 500 directional calls were created. In the system in which all methods are tested in line with these calls, a decrease in people’s average waiting periods was observed [10]. In another study for average waiting time, a simulation environment consisting of 16 floors and 4 floors was created. In this study, a numeric keypad was used for people to enter their destination floors. Therefore target floors could be known beforehand. In addition to this, an artificial immune optimization algorithm was used in the study in order to for the cabins to detect the optimal way [11]. In another study on the same field, a fuzzy group elevator control algorithm was proposed. In this study, there are five different control algorithms based on FPGA. An example of block diagram summarizing this structure which consists of four different modules is as seen in Fig. 1 [12].

![Diagram](image_url)

Fig. 1 The proposed approach in literature [12]

In another study which proposes a different point of view to analyse group elevators, the aim was to create double cabin elevator systems. In this approach, which was applied on group elevator systems, genetic network programming
technique was used and it was revealed that the proposed approach diminished waiting and traveling periods in different building traffics. The block diagram to summarize the system used in this study is given in Fig. 2 [13]. Another issue to take into account in group elevator systems is energy efficiency. In another study, in addition to minimizing cabins’ average waiting and traveling times, an adaptive control system with the aim of diminishing energy use was proposed. In this approach, genetic algorithm, clonal selection algorithm, DNA algorithm and estimating algorithm was used. Besides, in this system, a fuzzy structure was created to make effective use of these algorithms. The proposed system calculates average waiting and traveling periods and energy amounts to be used by the cabins to detect the optimal solution. An example block diagram of this paper is presented in Fig. 3 [14].

In this study, a genetic algorithm was used for time efficiency optimization of group elevator systems. Within the scope of the study, an experimental setup of 10 floors and 5 cabins was established and optimization algorithm was tested on this system. On the established experimental setup, people could enter their destination floors thanks to numeric keypad. Directional floor call keys were also used. Also, optimization algorithm was applied on both call types and system behaviour was studied. In line with these objectives, details of the optimization algorithm was given in part two. In part three, work patterns of the elevator control system was referred to and in part four, experimental results were included. In the fifth and the last parts of the study, results were presented.

II. GENETIC ALGORITHM FOR ELEVATOR CONTROL SYSTEM

Control and optimization of a group elevator system is an important issue. Using optimization techniques in these systems for usage of elevator cabins ideally and for the elevator to provide its services to the people is a must. In the study performed with this objective, genetic algorithm was used and minimizing people’s waiting period was aimed.

Genetic algorithm is an optimization technique which is commonly used in literature and applied in many fields [15, 16]. Pseudo code of this approach which aims best ideal solution in big solution space is shown step by step in Fig. 4.

<table>
<thead>
<tr>
<th>Genetic Algorithm Pseudo Code</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1:</strong> Initial population of randomly generated sequences of binary numbers</td>
</tr>
<tr>
<td><strong>Step 2:</strong> A certain amount of element is selected for the solution</td>
</tr>
<tr>
<td><strong>Step 3:</strong> Crossing is applied to new population</td>
</tr>
<tr>
<td><strong>Step 4:</strong> Mutation process is applied for the same population</td>
</tr>
<tr>
<td><strong>Step 5:</strong> Affinity values of elements of these populations are found</td>
</tr>
<tr>
<td><strong>Step 6:</strong> 2. step is repeated until it reaches the maximum number of transactions</td>
</tr>
</tbody>
</table>

![Fig. 4 Genetic algorithm pseudo code](image)

One of the most important difficulties encountered in organization methods is specifying objective function. Objective function, which is of utmost importance in problem solving, is seen as in Equation 1 for group elevator system.

\[
Affinity = (|k - l|) \times T_R \times a_1 + T_D \times a_2
\] (1)

\[k = Elevator’s \ floor\]
\[l = Elevator’s \ target \ floor\]
\[T_R = Elevator’s \ average \ passing \ time \ between \ two \ floors\]
\[T_D = Elevator’s \ door \ openin \ closing \ time\]
\[a_1 = Equation \ weight \ (0.8)\]
\[a_2 = Equation \ weight \ (0.2)\]

Genetic algorithms are one of the most frequently used optimization techniques. One of the principle reasons for this is that genetic algorithms are able to offer really fast and effective solutions in big solution spaces. Therefore, this method was chosen for the study and used for control and optimization of group elevators.
III. PROPOSED ELEVATOR CONTROL APPROACH

In order to put the proposed approach into practice, an elevator prototype was developed which worked in line with the real elevators. This system has 10 floors and 5 cabins. Dial calls are designed both as directional and as in a way which destination floor can be entered. For this purpose, a numeric keypad is integrated onto the system. An example block diagram on the designed system can be seen in Fig. 5.

In the designed system there are seven segment displays on each cabin and these displays show the floor the cabin is on. There is also a 2x16 LCD screen placed on top of the system. In this group elevator system of 10 floors and 5 cabins, Can Bus communication standard is used. Communication of the system with the outer world is established with an RS-232 port via serial communication systems. Data is both transferred and read through this network. Various data polls were created on main computer line for measuring performance of the system and these calls are transferred to the processor controlling the elevator. Therefore performance tests could be made and statistical information could be obtained.

On the system, the tests are made through three different ways. These are elevator control approach using classical directional floor call, elevator control approach based on directional floor call based on optimization and elevator control approach using numeric keypad. The system receives calls from call pool, floor and cabin numbers, cabin position and direction information as an entry. Then it applies the chosen one of the 3 proposed methods onto the system. When this frame is considered, diagram for the proposed approach is as seen in Fig. 6. In addition to this, a block diagram to summarize the way the system works is shown in Fig. 7.
IV. EXPERIMENTAL RESULTS
In this study, group elevator systems’ control and optimization were performed. For this purpose, an elevator system of 10 floors and 5 cabins was established and optimization of incoming floor calls was performed using genetic algorithms. With this optimization process, minimizing people’s waiting period was aimed. Three different situations were taken into account in tests. First of them is the system using classical methods and directional buttons. In this application, the system works in line with the logic of closest floor. In other words, the cabin which stands closest to the floor from which the call is made is transferred to the floor. In the second scenario, optimization of these directional calls is managed with genetic algorithms. A call pool of random directions and these calls are optimized with genetic algorithm. In the third and last scenario, a numeric keypad integrated onto elevator prototype was used. This allowed people to enter the destination floor they want to be on. The most important advantage of this method is the capacity to know of destination floors beforehand. An image of experimental setup established within this framework is shown in Fig. 8 and 9.

Fig. 8 The experimental setup
Fig. 9 The cabinets, display and numerical keypad

There are basically three different traffic periods in elevator systems. These are respectively up-peak, down-peak and interfloor. Up-peak is the period which is encountered usually in the mornings, when people are keen to travel upstairs. Down-peak is the period encountered at the end of the shift, when people are keen to travel downstairs. Interfloor traffic is the type of traffic encountered between floors during the day. Interfloor traffic was taken into account in this study. In calls with random directions created in line with this situation, the number of downward and upward calls are approximately the same. Details of the building and the cabins are given on Table 1. In addition, starting locations of cabins are kept fixed and cabins’ location and direction information is given on Table 2.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>BUILDING AND ELEVATOR FEATURES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element</td>
<td>Values</td>
</tr>
<tr>
<td>Number of floors</td>
<td>10</td>
</tr>
<tr>
<td>Number of elevators</td>
<td>5</td>
</tr>
<tr>
<td>Floor height (cm)</td>
<td>17</td>
</tr>
<tr>
<td>Speed (cm/s)</td>
<td>5</td>
</tr>
<tr>
<td>Number of calls</td>
<td>500</td>
</tr>
<tr>
<td>Number of up direction calls</td>
<td>289</td>
</tr>
<tr>
<td>Number of down direction calls</td>
<td>211</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>FLOOR AND DIRECTION OF CABINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabin No</td>
<td>Floor</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

As reported in the very beginning of the report, three different applications were developed on the system. Random calls created in the beginning phase are tested and system behavior was examined. In this process, average waiting periods were consistently measured and a graphic indicating the results of this change can be seen in Fig. 10.
As it can be seen in Fig. 10, the ideal solution of three different tests turned out to be the one in which numeric keypad and optimization were used together. Besides, classical method offered provided the worst performance. In the light of this data, Table 3 shows average waiting periods assessed for system performance as well as the percentage of CPU usage.

Fig. 10 Average waiting times for three different test conditions.

TABLE IIIIIII
PERFORMANCE OF METHODS

<table>
<thead>
<tr>
<th></th>
<th>Classic</th>
<th>Optimization</th>
<th>Keypad</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWT (s)</td>
<td>18.01</td>
<td>16.67</td>
<td>14.54</td>
</tr>
<tr>
<td>~CPU (%)</td>
<td>11</td>
<td>63</td>
<td>35</td>
</tr>
</tbody>
</table>

As it can also be seen on Table 3, the systems in which numeric keypads were used turned out 23.8% more efficient, which means these systems provided a 14.6% more performance level when compared to the approach in which the optimization technique is used. When CPU usage data is analysed, the reason that classical method is the most advantageous one is that it steers the cabins according to the closest floor principle. When optimized system and the system with numeric keypad are compared by means of CPU performance, numeric keypad system is on step ahead.

V. CONCLUSIONS

Group elevators were optimized with the study’s proposed approach. With this objective, a prototype of a group elevator system of 10 floors and 5 cabins was set up and tests progressed on this experimental setup in real time. A numeric keypad system was integrated into the elevator, different from classical elevator systems, and the people were allowed to enter their destination floor before they get on the elevator.

In this approach, genetic algorithm was chosen for the method of organization. This algorithm is fast and efficient, paving the way to its preferable. Three different approaches were taken in testing process. As a result of the studies, the control system with numeric keypad worked better. Thanks to this new approach, a 20% more efficiency could be get and a 14% gain could be managed when compared to the systems in which only optimization techniques were used.

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DEEP BELIEF NETWORK BASED BRAIN ACTIVITY CLASSIFICATION USING EEG FROM SLOW CORTICAL POTENTIALS IN STROKE

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Abstract— An electroencephalogram (EEG) is an electrical activity which is recorded from the scalp over the sensorimotor cortex during vigilance or sleeping conditions of subjects. It can be used to detect potential problems associated with brain disorders. The aim of this study is assessing the clinical usefulness of EEG which is recorded from slow cortical potentials (SCP) training in stroke patients using Deep belief network (DBN) which has a greedy layer wise training using Restricted Boltzmann Machines based unsupervised weight and bias evaluation and neural network based supervised training. EEGs are recorded during eight SCP neurofeedback sessions from two stroke patients with a sampling rate of 256 Hz. All EEGs are filtered with a low pass filter. Hilbert-Huang Transform is applied to the trails and various numbers of Instinct Mode Functions (IMFs) are obtained. High order statistics and standard statistics are extracted from IMFs to create the dataset. The proposed DBN-based brain activity classification has discriminated positivity and negativity tasks in stroke patients and has achieved high rates of 90.30%, 96.58%, and 91.15%, for sensitivity, selectivity, and accuracy, respectively.

Keywords— Deep Belief Networks, SCP, Slow Cortical potentials, Hilbert-Huang Transform, EEG

I. INTRODUCTION

An electroencephalogram (EEG) is a biomedical signal that records the electrical activity in the brain [1]. The neurons connect to each other by the dendrites and axons in the brain. The communication between the neurons is provided by the electrical impulses over the dendrites and axons. The electrical activity in the brain can be recorded and monitored placing the electrodes to specific areas on the head [2]. The placement of the electrodes and the channel names are seen in Figure 1. The EEG is used in several areas such as providing the interaction between human and machine [3], [4], determining the response of the brain to the visual and auditory signals [5], [6], allowing the diagnosis of psycho-physiological and neurological disorders [7]–[11], and helping doctors to make a quick assessment of normal and abnormal patterns using the peaks and valleys on the EEG for all age groups. Seizure disorders (such as epilepsy), a head injury, encephalitis, a brain tumour, encephalopathy, memory problems, sleep disorders, stroke, dementia, and etc. are the diagnosable brain disorders using an EEG. The normal electrical activity of the brain is disrupted in many neurological disorders and brain potentials [2]. The kind of the disorder can be stated by evaluating the shape and the interval of the disruptions on the EEG. EEG carries characteristic features that are helpful in the early diagnosis and early treatment processes of psycho-physiological and neurological disorders [11].

Slow cortical potential (SCP) is gradual changes in the cortical layer and the regulation of cortical excitability in cortical neuronal networks [12]. The SCP has a duration that varies between 300ms and 10s [13]. The SCP is a low-frequency EEG component and a non-invasive method. The electrodes are placed on the top center of the head and conditioned responses method used in giving feedback. Due to these characteristics, the SCP may include the contingent negative variation, readiness potential, movement-related potentials, P300 and N400 potentials [1]. Negative SCP is assumed to depolarization of cortical neuronal cells and
positive SCP shows neuronal complication [13]. The SCP has been correlated with a large number of cognitive processes in a systematic and topographically ways and has been determinately utilized in psychophysiological experiments to dissociate cognitive functions and motor performance of the brain [14], [15]. Ergenoglu et al. worked on determining the relationship between SCP and P300 amplitude [12], Khader et al. analysed the relations between the SCP and Blood-oxygen-level dependent (BOLD) signal changes [16], Devrim et al. investigated the detection of visual stimuli at sensory threshold using the SCP [6], Kotchoubey et al. used the SCP training in the research on epilepsy with analysis of influencing factors [7], [8]. Strehl et al. used functional magnetic resonance imaging and the BOLD signal in the SCP to reduce epileptic seizure frequency [17], Sniatchkin et al. evaluated the analysis of migraine [9], Schneider et al. determined the efficiency of the SCP training in psychiatric patients with alcohol dependency[10], Cosch et al. associated the SCP with the event-related potentials such as object, spatial, and verbal information [4], Hinterberger et al. suggested a robust and steady communication method between computer and brain for amyotrophic lateral sclerosis patients using the SCP and studied on developing a tough translation device [3], Pham et al. developed an auditory brain-computer stimuli for paralyzed patients using the SCP [5].

Stroke is a brain disorder that causes when the blood supply of brain cells is either cut off or reduced and the cells began to die. The abilities controlled by dead cells such as memory and muscle control are lost. The disorder affects the EEG and can be declared from the SCP and more potential.

Deep Learning (DL) is an invasive, effective and machine learning algorithm that has a growing popularity and attempts to model high-level abstractions [18]. In recent years, the DL is a new method of Machine Learning researches, which has been recognized with image processing, character recognition, speech recognition, frequently. Convolutional Neural Networks, Stacked Auto-encoders, Deep Boltzmann Machines and Deep Belief Networks (DBN) are the most effective DL algorithms [19]. The biggest advantage of the DL is representing handcrafted features with the efficient algorithms for unsupervised or supervised feature learning and hierarchical feature extraction [20]. In this study, the DBN algorithm is utilized as the classifier. The DBN is a robust and simple type of the DL algorithms which is comprised of both supervised and unsupervised learning stages. The experimental results that are obtained with the same number of hidden units and same structure of the DBN are compared with artificial neural network (ANN).

In the following section, the SCP training database, Hilbert-Huang Transform (HHT), the HHT-based statistical feature extraction processes, and the DBN classifier are described in detail. The proposed SCP training classification system is explained. The experimental results that are obtained using the DBN classifier are presented.

II. MATERIAL AND METHODS

In this section, the SCP training database, the pre-processing of the database, Hilbert-Huang Transform, and statistical feature extraction methods would be explained.

A. Database

The EEG is an electrical activity which is recorded from the scalp over the sensorimotor cortex during vigilance or sleeping conditions of subjects. It can be used to detect potential problems associated with brain disorders. EEG data were recorded during eight SCP neurofeedback sessions from two chronic stroke patients [21]. Neurofeedback sessions were conducted with an approximate interval of one week between sessions.

The EEG was recorded with a sampling rate of 256 Hz from channel Cz using a Nexus-10 MKII DC amplifier (Mindmedia, Herten, The Netherlands). Each neurofeedback session included trials in which cortical positivity had to be increased and trials in which cortical negativity had to be increased. The durational presentation of the trials is 8s and is seen in Figure 2. The feedback includes a circle with the different size and colour related with the subject set successfully to baseline activity. The brain activities are labelled successful as positivity, and success indicated to the participant as negativity, if the trials are evaluated according to the task correctly, or not, respectively.

![Fig. 2 Timeline of a trial from neurofeedback session](image)

All EEGs were filtered with a low pass filter (10 Hz). The negativity trials in SCP training sessions more frequent than the positivity trials. A total number of 8000 trials (500 trials for each session and each patient) with 2400 data points were segmented from 2 of EEGs. Distribution of the trials according to positivity and negativity situation in the database is given in Table I.

| TABLE I | STIMULI TRIAL DISTRIBUTION OF EACH STROKE PATIENT |
|---|---|---|
| Sessions | # Negativity Trials | # Positivity Trials |
| Session 1-3 | 250 | 250 |
| Session 4-8 | 375 | 125 |
| Total | 2625 | 1375 |

B. Hilbert-Huang Transform

Hilbert-Huang Transform is a method that has a frequently use for feature extraction, filtering the signals, and similar processes on nonlinear and non-stationary signals. The growing trend on analysis of non-stationary and non-linear has led to opportunities of the analysis to expand the technical requirements [22]. The HHT is one of the adaptive and extensive methods that can be considered as relatively recent.
The HHT has been applied to lots of fields such as biomedical signal processing and geophysics [23].

Due to the flexibility of the stoppage criteria of the HHT algorithm, mathematical description of the HHT algorithm could not be defined precisely and clearly [24]. The HHT has a two-step analysis. The first step is Empirical Mode Decomposition (EMD), and the second step is Hilbert Transform (HT), respectively. The EMD is pre-treatment of the original data and extracts \( n \) number of Intrinsic Mode Functions (IMF) and a residual signal. Each IMF is a signal which is based on a frequency modulation of the original data. The HT performs to obtain instantaneous frequency and amplitude values of each IMFs in the time-frequency domain [11], [24]. The HHT can perform more precise, distinctive and clear results than other methods in the presentation of time-frequency-energy for non-stationary and nonlinear signals [25].

1) Empirical Mode Decomposition: The EMD is a flexible analysis method which is used for extracting characteristic information obtained from non-linear and non-stationary processes. The most important characteristic of the EMD that is separated from other transformation algorithms is producing self-distinct oscillation of the original data by assuming that the signal consists of self-oscillations modes at the different frequency bands [26]. Each oscillation is symmetrical relative to local mean of local extrema. Each different oscillation in the signal is indicated by an IMF. The IMFs are extracted from the signal by following two basic conditions[24], [25]:

- The number of the local extrema and zero-crossing must be either same or difference must be equal to one
- The mean of the upper and lower envelopes which are obtained by the combination of the local maximum and local minimum must be equal at any time

The stated IMF extraction conditions are used for preventing negative frequency and keeping the instantaneous frequency of narrow-band signals in the frequency band while calculating the instantaneous frequency information [11].

The local mean is calculated taking the average of the local minimums and the upper envelope defined by local maximums. The local mean is subtracted from the original signal and the new form of the signal is controlled verifying if it is an IMF. If the new form of the signal does not satisfy the IMF extraction conditions, the local mean is recalculated using the local maximums and local minimums of new signal. This calculation is performed until an IMF is extracted. The residual signal is obtained subtracting the IMFs from last form of the residual signal. When the residual signal is a monotonic function or the residual signal has only one local extreme, it is not possible to extract another IMF and the EMD process ends [11], [23], [24]. \( r(t) \) represents for the last residual signal, \( x(t) \) indicates the original signal, and \( n \) is the number of the IMF.

\[
x(t) = \sum_{i=1}^{n} IMF_i(t) + r(t)
\]

2) Hilbert Transform: The foremost characteristic feature of the non-linear signals is the internal wave frequency modulation that shows the instantaneous frequency oscillation in a single period. The signal characteristics are indicated straightforwardly by the instantaneous frequency distribution. The HT is a decomposition which determines the amplitude-frequency-time distribution of the signal [23], [26]. The HT of a signal is defined as:

\[
x(t) = \Re \left\{ \sum_{i=1}^{n} a_i(t) e^{i \omega_i(t) t} \right\}
\]

\( a_i \) indicates the amplitude function of the signal, \( \omega_i \) represents for the instantaneous frequency function. The frequency-time distribution of the amplitude is called as Hilbert Spectrum and is shown as \( H(\omega, t) \).

\[
h(\omega) = \int_0^T H(\omega, t) dt
\]

The above equations show each IMF is amplitude and frequency modulated signals. The EMD proves its impact by analysing the non-stationary signals in the variable amplitude and frequency scales.

C. Deep Belief Networks

The DBN is a generative DL algorithm that consists of both unsupervised training and supervised training phases. The most important feature of the DBN is the idea of pre-training the weights, biases, and the other parameters using an unsupervised training algorithm such as Sparse Autoencoder or Restricted Boltzmann Machines (RBM) [18], [27]. In this study, the RBM is selected as pre-training algorithm in unsupervised training phase. The RBM is a stochastic ANN type that calculates the weights of the units according to the probability distribution over a set of inputs. The stacking of the RBMs can build up the DBN with gradient descent algorithm or contrastive divergence algorithms [28]. In the RBM, visible units that represent input data are connected to hidden units that learn to represent features using undirected weighted connections [19], [28].Considering the RBM with input layer activations \( v \) (for visible units) and hidden layer activations \( h \) (hidden units), bias of the visible unit \( b \), bias of the hidden unit \( c \):

\[
E(v,h) = -hWv - bv - ch
\]

\[
P(v,h) = \frac{e^{-E(v,h)}}{\sum e^{-E(v,h)}}
\]

\( P(v,h) \) indicates the joint distribution of the RBM and \( E(v,h) \) represents for the energy function of the distribution. The DBN used latent variables in the deepest layer easy to understand the deepest features using at least two hidden layers in network. Each adjacent two layers have a connection to evaluate the greedily layer-wise pre-training [18]. The parameters such as the weights and the biases obtained in
unsupervised learning phase are unfolded to a neural network structure. The pre-trained parameters are updated and fine-tuned in supervising training phase. The whole network can be optimized by gradient descent algorithm in this learning phase. The detailed formulation about the DBN is presented in [18], [29].

III. EXPERIMENTAL RESULTS

The brain computer interfaces allow setting a connection between the machines and the brain to control devices with the SCP and more. The SCP training neurofeedback sessions are used to make a quick assessment of normal and abnormal patterns in the diagnosis of psycho-physiological and neurological disorders using the peaks and valleys from the EEG. The aim of this study is classifying the brain activities from the SCP training in stroke patients and pointing out the negativity and positivity trails in the neurofeedback.

The SCP training trials have been related with a large number of cognitive functions, motor performance of the brain and many neurological disorders in literature. Ergenoglu et al. worked with the positivity and negativity SCP trials to getting a connection between the SCP trainings and P300 amplitude and experienced the P300 amplitudes of trials with the negative SCPs are significantly higher in comparison with the positive SCPs at Cz, Pz, Fz, P3, and P4 channels under normal and abnormal conditions of the brain [12], Khader et al. investigated the relations between the SCP and Blood-oxygen-level dependent (BOLD) signal changes and proposed the similar topographical specificity of the SCP trials and the BOLD signal under cognitive experiments [16], Devrim et al. investigated the detection of visual stimuli at sensory threshold using the SCP and the negative SCP trials have a better separation ability than the positive SCP trials at Oz, Pz, Cz, and Fz channels [6]. Kotchoubey et al. analysed the influencing factors in epilepsy using twenty sessions SCP training and detected the positive trials are more important than the negative trials [7], [8]. Strehl et al. used functional magnetic resonance imaging and the BOLD signal in the SCP and reduced epileptic seizure frequency [17], Siniaitchkin et al. evaluated the analysis of individual differences in migraine and experienced the negative trials from the SCP differed significantly between the individual habitat [9], Schneider et al. determined the efficiency of the SCP training with self-regulation task utilizing biofeedback and instrumental conditioning in psychiatric patients with alcohol dependency [10], Hinterberger et al. developed a tough translation device for ALS patients using the SCP trials [3], Pham et al. developed an auditory brain-computer stimuli for paralysed patients using the SCP and discussed auditory stimuli characteristics may have to be adapted to optimize brain-computer interface performances [5]. The studies based on cognitive functions, motor performance of the brain and many neurological disorders in literature are indicated the efficiency and the importance of the SCP training and classification of the brain activities from the SCP training such as negativity trials or positivity trials in stroke patients.

The HHT is an effective method on non-linear and non-stationary EEG signals. Huang et al. [25] proposed a communication between human and computer. They used the HHT and wavelet transform for extracting the features from the steady-state visual evoked potential and indicated the HHT is more accurately expressing the time and frequency characteristics ability than the wavelet transform. Li et al. [30] proposed a sleep stage classification method using the EEG. They achieved a classification mean accuracy of 81.7% using the HHT, Fourier transform and wavelet transform features and discussed that the HHT is more successful and faster response for extracting the EEG features and tracking the rapid changes. Ozdemir et al. [11] and Oweis et al [22] applied the HHT to EEG and used intra wave frequency modulation on the different frequency bands to diagnose epileptic seizure prediction and classification and achieved accuracy rates of 89.66% and 94%, respectively. Considering these achievements of the HHT on EEG, we decided to utilize the HHT in the feature extraction of the brain activity classification from the SCP training in stroke.

The proposed method consists of preparing EEG signal, analysing EEG using the HHT and the HHT-based statistical feature extraction stage and the DBN-based brain activity classification stage. To provide the different definitive and descriptive situations in patient and recording process of the SCP training, the dataset with eight of the SCP neurofeedback sessions that were conducted with an approximate interval of one week from two chronic stroke patients is selected. A low pass filter is applied to remove the potential noises and peaks in the EEG. 8000 of the SCP trials with 2400 data points were extracted from the stroke patient EEGs. The extracted EEG trials are labelled as cortical negativity and positivity in the dataset.

The EMD is applied to extracted trials with 2400 of data points. IMFs were obtained vary in the number from 5 to 8. Figure 3 depicts a random trial and the IMFs decomposed from the random trial. HT is applied to each IMF. The amplitude-frequency-time distribution of each IMF is determined. Statistical features such as standard deviation, correlation co-efficient, skewness, kurtosis, minimum, maximum, covariance, mode and mean, energy based features, high order statistical features such as moment and cumulants were calculated for each HT applied IMF and the feature set is created.

The half of the trials (1750 of the positivity trials and 2250 of the negativity trials) from all sessions of the neurofeedback is used for training of the DBN classifier model and the remaining trials are reserved for testing the proposed DBN system.
The proposed DBN has 2 brain activities in SCP (Positivity, Negativity) as outputs. Figure 4 indicates the structure of the proposed DBN classifier with visible and 3 hidden layers. The RBM based greedy layer-wise pre-training is used in this model at the unsupervised learning stages of the DBN with 100 epochs. The optimization parameters such as learning rate, activation function of the supervised learning phase, output function of the DBN, and the number of the hidden units of the RBM were denoted by iterations. The models were tested with a limited number of the parameters and the highest classification performances are given. The learning rate of the model is 2 and the softmax output function was utilized in the DBN. The sigmoid activation function is selected in the all validations and training sessions. The DBN has 3 hidden layers with 350-100-260 hidden units, respectively. The confusion matrix of the proposed classifier is seen in Table II.

<table>
<thead>
<tr>
<th>Labels</th>
<th>Predicted Trials</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positivity</td>
</tr>
<tr>
<td>Truly Classified Trials</td>
<td>953</td>
</tr>
<tr>
<td>Positivity</td>
<td>97</td>
</tr>
</tbody>
</table>

The classification performances are statistical valuation functions: Specificity, Sensitivity, and Accuracy which are obtained from confusion matrix of the classification. The formulation of the performance measurements are described in detail by Allahverdi et al. [29]. The achieved classification performances using both the DBN classifier and the ANN with same number of hidden units in 2 or 3 hidden layers are presented in Table III. The DBN and the ANN classifiers used same optimized learning rate, epochs, activation and output functions and hidden layer structures. The DBN structure with 3 hidden layers presented the highest accuracy of almost 91.15% using features from all sessions in neurofeedback.
TABLE III
THE CLASSIFICATION PERFORMANCES ACCORDING TO CLASSIFIER STRUCTURES

<table>
<thead>
<tr>
<th>Structure</th>
<th>Classification Performances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hidden Units</td>
<td>Classifier</td>
</tr>
<tr>
<td>120-250 units</td>
<td>DBN</td>
</tr>
<tr>
<td>120-250 units</td>
<td>ANN</td>
</tr>
<tr>
<td>190-100 units</td>
<td>DBN</td>
</tr>
<tr>
<td>190-100 units</td>
<td>ANN</td>
</tr>
<tr>
<td>30-60-45 units</td>
<td>DBN</td>
</tr>
<tr>
<td>30-60-45 units</td>
<td>ANN</td>
</tr>
<tr>
<td>350-100-260 units</td>
<td>ANN</td>
</tr>
<tr>
<td>350-100-260 units</td>
<td>DBN</td>
</tr>
</tbody>
</table>

It is hard to compare the success of the proposed system because of there is no reported study yet that we could find in our detailed literature search on the SCP training in stroke. In this study, the classification of brain activity in stroke patients is an overcome process using the SCP training. There is a strong correlation between brain activity and the SCP trials in stroke. The DL algorithms with the HHT-based statistical features have achieved a high classification performance of 90.30%, 96.58%, and 91.15%, for sensitivity, selectivity, and accuracy, respectively.

IV. CONCLUSIONS
The communication between the brain and computerized methods provides identifying the electrical neural patterns as a thought - before the pattern has fully manifested in to a conscious feeling, allows paralysed people to control prosthetic limbs with their mind and helps to diagnose the psycho-physiological and neurological disorders to clinicians. The proposed technique is a DBN classification method to detect the brain activity using the trials from SCP training in stroke. The achieved results indicate the efficiency of the HHT-based statistical features and the DBN when used together on EEG. The proposed system bears classifying the positivity and negativity trials with high accuracy, sensitivity, and specificity achievements. The present results suggest that the DBN classifier is more successful when compared with ANN in the classification of the brain activity from the SCP training in stroke for the HHT-based statistical and high order statistical features.

REFERENCES


ARRHYTHMIA CLASSIFICATION USING WAVEFORM ECG SIGNALS

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Abstract— An electrocardiogram (ECG) is a non-linear and non-stationary diagnostic biomedical signal that has a great importance for cardiac disorders. The computer-assisted analysis of biomedical signals has become an essential tool in recent years. This study introduces a deep learning application in automatic arrhythmia classification. The proposed model consists of a multi-stage classification system in raw ECG using a Deep belief network (DBN) which has a greedy layer wise training phase. The multistage DBN model classified the MIT-BIH Arrhythmia Database heartbeats into 5 main groups defined by ANSI/AAMI standards. All ECGs are filtered with median filters to remove the baseline wander. ECG waveforms were segmented from long-term ECGs using a window with a length of 501 data points (R peak of the wave is located at the centre of the window). The proposed DBN-based multistage arrhythmia classification has discriminated five types of heartbeats with a high accuracy rate of 95.05%.

Keywords— Arrhythmia, Deep Belief Networks, Deep Learning, AAMI, Raw ECG Waveform

I. INTRODUCTION

According to the World Health Organization surveys [1], heart diseases are one of the most important reasons which cause death. Heart disease symptoms depend on what type of heart disease you have. An electrocardiogram (ECG) is a non-linear and non-stationary diagnostic signal that is important for cardiac disorders [2]. It is hard to assess a cardiac disorder using ECG because of long processes that need a control in detail and infrequent arrhythmias. In order to overcome these challenges, the computer-assisted analysis of biomedical signals has become an essential method in recent years. The computer assisted diagnosis and analysis systems achieve rapid and advanced assessments in long, and hard to identify processes. Arrhythmia and many cardiac disorders usually need to use long-term ECG in inspection controls [3]. Therefore, computer-based methods and diagnosis systems provide major simplicity and reliability in the diagnosis and treatment of the diseases for cardiologists.

Arrhythmia is a problem concerning the abnormal rhythm and rate of heartbeats. The heart can beat too fast, too slowly, or inconsistently in different types of arrhythmias, which may feel like antagonism affection or fluttering. Arrhythmia may be classified by rate of heartbeats, mechanism (automaticity, re-entry, triggered) or duration of the heartbeats [4]. Several types of arrhythmia are harmless, but some of them refer the cardiac disorders that may cause death. The ECG is a popular diagnosis tool which is of the primary importance for cardiologists [5].

There are many studies that are used for detecting arrhythmias, classifying them and diagnosing cardiac diseases that occur as a result of arrhythmias. These studies can be incorporated into two basic feature extractions: fiducial and non-fiducial methods. The fiducial methods contain the local features such as temporal, morphological, amplitude, duration, interval and segments between two selected waves which are extracted from ECG waveforms. These methods are based on the time-domain features on the ECG [6]. The non-fiducial methods are based on the frequency-domain features such as wavelet transformations, and the other digital signal processing techniques that extract new signal forms, sub-bands and coefficients from ECG waveforms [7].

Deep learning (DL) is an effective and high-performance machine learning algorithm which is gaining popularity. Frequently used analyses of the DL are used in image processing, speech and natural language processing processes. Actually, DL is a neural network structure which addresses the deeper feature levels using more hidden layers [8]. In this study, Deep Belief Networks (DBN), which is an adaptable DL algorithm, is utilized to classify the heartbeats from different classes of arrhythmia using ECG waveform as input of the structure.

The remainder of the paper is structured in the following manner. The database and the arrhythmia types are defined by AAMI standards, pre-processing, and feature extraction from arrhythmia heartbeats are described in detail. The proposed multistage classification system is explained. The experimental results that are obtained using the DBN classifier are presented.
II. MATERIALS AND METHODS

The general management of medical treatment and assessment systems has become effective and convenient processes because of the recent technological developments in integrated circuit systems and computer-aided intelligent monitoring and diagnosis systems. In this section, information about ECG waveforms and the DBN classifier are described in detail.

A. Database

There are several arrhythmia databases in the literature. In this study, the MIT-BIH arrhythmia database (MADB) is utilized [9]. This database has been used for evaluating arrhythmia detection and classifying the arrhythmia types. MADB contains 48 long-term ECGs from 25 men aged 32–89 years, and 22 women aged 23–89 years; each has 11-bit resolution with 360 Hz sampling frequency. The heartbeats are labelled as five main arrhythmia types defined by the Association for the Advancement of Medical Instruments (AAMI) standard. AAMI standardizations provide an objective, understanding, and individual assessments and monitoring processes of the arrhythmia types for clinical treatments and an increased capability of testing and training abilities for supervised learning phases [10]. AAMI classifies heartbeats into normal beats (N), supraventricular ectopic heartbeats (S), ventricular ectopic heartbeats (V), fusion heartbeats (F), and unknown heartbeats (Q). The testing and training dispersions of the heartbeats from the MADB are seen in Table I.

<table>
<thead>
<tr>
<th>AAMI classes</th>
<th>MIT-BIH heartbeat classes</th>
<th>Train Set</th>
<th>Test Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Normal beat</td>
<td>350</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Left bundle branch block beat</td>
<td>350</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Right bundle branch block beat</td>
<td>350</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Nodal escape beat</td>
<td>114</td>
<td>113</td>
</tr>
<tr>
<td></td>
<td>Atrial escape beat</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>S</td>
<td>Aberrated atrial premature beat</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>Premature or ectopic supraventricular atrial premature contraction beat</td>
<td>350</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Atrial premature contraction beat</td>
<td>42</td>
<td>41</td>
</tr>
<tr>
<td>V</td>
<td>Ventricular flutter wave beat</td>
<td>236</td>
<td>236</td>
</tr>
<tr>
<td></td>
<td>Ventricular escape beat</td>
<td>53</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Premature ventricular contraction beat</td>
<td>350</td>
<td>250</td>
</tr>
<tr>
<td>F</td>
<td>Fusion of ventricular and normal beat</td>
<td>350</td>
<td>350</td>
</tr>
<tr>
<td>Q</td>
<td>Paced beat</td>
<td>350</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Unclassifiable beat</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Fusion of paced and normal beat</td>
<td>350</td>
<td>250</td>
</tr>
</tbody>
</table>

Long-term ECG signals can be contaminated by several types of noise, such as motion during ECG recording, electromyogram noise, contact noise, clinician artefacts, coughing, position of patient, baseline wandering, etc. All ECGs are filtered with two median filters to remove the baseline wander [11]. 6077 short-term ECGs were segmented from long-term ECGs using a window with a length of 501 data points (R peak of the wave is located at the center of window). All data points are normalized to a [0, 1] range.

B. ECG Waveform

The ECG is a method that finds out the regularity or irregularity of heart beats and heart rates using the electrical activity of the heart. The recorded electrical activities of the heart represent for a waveform on the clinical assessments. These waveforms may have different forms according to the lead of the ECG [11], [12]. The use of the ECG in medical assessment processes is very important in detecting the different waveforms and various cardiovascular heart diseases.

In the entire body only the heart muscle has the ability to contract spontaneously. Polarity is the event of discharge of electrical charge of heart tissue. Depolarization is the positive charging case of electrical activation in heart tissue [13].

The ECG has 0 mV to 5 mV amplitude and a frequency band between 0.5 Hz and 100 Hz [2], [13]. P, Q, R, S, T and U waves appear over the baseline in the signal, respectively. If the amplitude of Q, R and S waves is less than 5 mV, the wave is referred to using small capitals (q, r, and s). The remaining portion between the waves is a segment; the distance between the waves is an interval [12].

A P wave occurs as the result of the depolarization of the atrium. First, the right atrium then the left atrium, depolarizes. Therefore, the first part of the P wave occurs when the right atrium depolarizes; second part of the P wave occurs when the left atrium depolarizes. Although it depends on the time of the year, the duration of the P wave is about 0.11 seconds; the amplitude of the P wave is between 0.18 mV and 0.22 mV on a normal lead [2].

The QRS complex occurs as the result of the depolarization of the ventricles. One of the waves (R) forming the QRS complex is positive; the other two waves (Q and S) are negative. The Q wave represents the first negative wave after the P wave; the R wave represents the first positive wave after the P wave and the S wave represents the next negative wave after the R wave. The QRS monitored complex varied in different leads. The QRS samples show significant differences even among normal individuals. R and S waves refer to the contraction of the myocardium. The QRS complex indicates the current causing the left and right ventricle contraction [14]. The QRS complex has the maximum amplitude between the ECG forms. The duration of the QRS complex does not
exceed 0.11 seconds and has an amplitude value up to 2-3 mV [2].

The T-wave occurs as a result of ventricular re-polarization. The T-wave may have a pointed or flat view and positive, negative or biphasic value on various leads. The duration of the T wave that belongs to a normal subject is between 0.10 and 0.25 seconds. It takes place after about 300ms from the QRS complex. The positions of these waves vary according to the heart rhythm. The T wave is closer to the QRS complex when the heart rhythm accelerates [14].

C. Deep Belief Networks

This study introduces a deep learning (DL) application for automatic arrhythmia classification. The proposed model consists of a multi-stage classification system of raw ECG using DL algorithms. The DBN is one of the most effective DL algorithms which has a greedy layer wise training phase [15]. The DBN is composed of both Restricted Boltzmann Machines (RBM) or an autoencoder based layer-by-layer unsupervised pre-training procedure and neural network based supervised training [8], [16]. Considering RBM with input layer activations $v$ (for visible units) and hidden layer activations $h$ (hidden units), bias of the visible unit $b$, bias of hidden unit $c$:

$$E(v,h) = -hWv - bv - ch$$  \hspace{1cm} (1)

$$P(v,h) = \frac{e^{-E(v,h)}}{\sum e^{-E(v,h)}}$$  \hspace{1cm} (2)

$P(v,h)$ represents the joint distribution of the RBM and $E(v,h)$ represents the energy function of the distribution. RBM is used for calculating the conditional distribution of the visible and hidden units. Each adjacent two layers create an RBM. The first visible unit is the input feature vector and the other RBM parameters $\theta = (W, b, c)$ are denoted by depending on the first visible unit [17].

In the unsupervised training phase, the sub-network's hidden layer serves as the visible layer for the next adjacent layer applying contrastive divergence and the probabilistically reconstruction of the shared weights is implemented [8]. In the supervised training phase of the DBN, the calculated shared weights and the structure of the DBN are unfolded to a neural network structure for fine-tuning all the parameters of the deep structure such as the weights and the biases [15]. The DBN consists of at least two hidden layers (latent variables) in the neural network. The number of the hidden layers is related to the deep analysis of the input features in detail [15], [17].

III. EXPERIMENTAL RESULTS

The morphological features are the ones most used in clinical trials for the diagnosis of the arrhythmia types. The robust and steady detection of arrhythmia is a common need for all the cardiac diseases. Each arrhythmia type can be related to different types of cardiac and pulmonary diseases. That’s why detection and classification of the arrhythmia types are so important in the early diagnosis and early treatment processes. Considering the importance of the classification of the arrhythmia types, a computer-aided classification of the 5 arrhythmia types is implemented using a DBN-based multistage classification. Figure 2 depicts the structure of the arrhythmia classification model.

Two median filters are applied to remove the noise and the baseline wanders to raw ECGs. Analysis of the long-term ECGs is a demanding process for clinicians and also for computer-aided systems. Considering this situation, ECG waveforms were extracted from long-term ECGs using the moving window analysis technique. The R peak centred window with 501 data points was moved to extract ECG waveforms. 6077 of ECG waveforms were obtained from long-term ECGs. ECG waveforms with 501 data points were directly used as features. Having a great number of the feature dimensionality causes long and deceiving training processes for the supervised machine learning algorithms. Feature dimensionality reduction for the provides for the extraction of more meaningful classification rules, the elimination of the pointless feature vector for machine learning algorithms, the improvement of generalization capabilities using fewer parameters and reduced complexity and run-time and for the evaluation and prediction of accuracy for classifiers [18]. The sequential forward feature selection algorithm is utilized in the proposed method to reduce feature dimensionality [19]. The algorithm selects a subset of features which are not yet selected from 501 data points and the best predict the arrhythmia types by sequentially selecting features until there is no improvement in the prediction. The highest accuracy is achieved using 106 features from the ECG waveforms. The reduced feature vector is normalized to 0-1. The proposed DBN-based multistage classifier was trained using 106 data points. Selected data points on the ECG waveform are seen in Figure 3 with the red asterisk.
The proposed multistage DBN model separates N, S, V, F, and Q types of arrhythmias, respectively. 4 of the DBN models are used in the proposed system. The RBM based greedy layer-wise pre-training is used in this model at the unsupervised learning stages of all DBNs with 5 epochs. The parameters of the RBM were denoted by iterations. The models were tested with a limited number of the parameters and the highest classification performances are given. The learning rate of the model is 3 and the softmax output function was utilized constantly. The proposed multistage arrhythmia classification model consists of 4 DBN structures with various numbers of hidden units. The DBN1 has 2 hidden layers with 100-260 hidden units; the DBN2 has 3 hidden layers with 230-520-210 hidden units; the DBN3 has 2 hidden layers with 120-240 hidden units; and the DBN4 has 2 hidden layers with 70-190 hidden units. The four DBN structures are connected sequentially and have the ability to separate five classes of arrhythmia types defined by ANSI/AAMI.

The training set of the DBN-based automatic arrhythmia classification model includes 4,077 of ECG waveforms from various types of heartbeat classes distributed homogeneously. The DBN-based multistage model is tested using 2,000 of ECG waveforms. The confusion matrix of the classifier is seen in Table II.

### TABLE II

<table>
<thead>
<tr>
<th>Labels</th>
<th>Predicted heartbeats</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>True heartbeats</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>489</td>
</tr>
<tr>
<td>S</td>
<td>0</td>
</tr>
<tr>
<td>V</td>
<td>2</td>
</tr>
<tr>
<td>F</td>
<td>4</td>
</tr>
<tr>
<td>Q</td>
<td>5</td>
</tr>
</tbody>
</table>

Zhang et al. used inter-beat features, amplitude morphology and morphological distance features for separating 4 types of arrhythmias by the Support Vector Machines (SVM) classification algorithm with 86.66%, 93.81%, and 98.98% for accuracy, sensitivity, and selectivity, respectively [20]. Melin et al. utilized cycle features and fiducial features with an Artificial Neural Network (ANN) and Learning Vector Quantization based multistage classification algorithm and classified 15 types of arrhythmia with an accuracy rate of 99.16% [21]. Thomas et al. extracted wavelet based coefficients from 4th and 5th scale of Wavelet transform, high order statistics and fiducial features using the QRS complex from the ECG with ANN and presented an accuracy rate of 94.64% and a sensitivity rate of 94.60% for 5 classes of arrhythmia types [22]. Batra et al. utilized invariant features and Principle Component Analysis features using the SVM classifier with the cross validation technique and achieved an accuracy rate of 84.82% for 11 classes of arrhythmia types [23]. Leutheser et al. compared the Naive Bayes and k-NN classifier algorithms using statistical and high order statistical features, heartbeat features and template based features from segmented ECGs for the real-time classification of 2 types of arrhythmias on Android-based mobile devices with reported accuracies of 93.30% and 56.10% for k-NN and Naive Bayes classifiers, respectively [24]. Alajlan et al. extracted morphological features, high order statistical features and non-fiducial features applying the Discrete wavelet transform, S transform and classified arrhythmia types into 2 classes using the SVM machine learning algorithm with high performances of 93.49%, and 93.14% for accuracy, and sensitivity, respectively [25].

DL algorithms, especially the DBN, are being effectively used in ECG analysis. The DBN is utilized at both feature extraction [26], [27] and classification stages [16], [28]. Huanhuan et al. used the DBN-based learning features from complete waveforms and R-R timing interval features with a multi-stage (5 stages) SVM classifier model. They achieved an accuracy rate of 98.82% for 6 classes of arrhythmia types [27]. Rahhal et al. extracted temporal features, morphological features and DBN-based features using stacked denoising autoencoders. They fed all features to the SVM for training and classification. They classified 2 classes of arrhythmia types defined by ANSI/AAMI with an overall accuracy rate of 98.49% [26]. Yan et al. utilized R-R interval features, beat features and raw ECG signals from multi lead to feed the DBN classifier and achieved a high accuracy rate of 98.82% for 12 classes of arrhythmia types [16]. There are lots of studies based on different types of arrhythmia classification. We focused on the arrhythmia types defined by ANSI/AAMI and the considerable studies are compared in Table 3.

### TABLE III

<table>
<thead>
<tr>
<th>Related Works</th>
<th>Features</th>
<th>Classifier</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owis et al. [29]</td>
<td>Correlation dimension, Lyapunov exponents</td>
<td>k-NN</td>
<td>86.67%</td>
</tr>
<tr>
<td>Martis et al. [30]</td>
<td>DWT, LDA, PCA</td>
<td>PNN</td>
<td>99.28%</td>
</tr>
<tr>
<td>Kim et al. [31]</td>
<td>CWT, Morphological feature, DWT, PCA, LDA</td>
<td>ELM</td>
<td>97.54%</td>
</tr>
<tr>
<td>Tadejko et al. [32]</td>
<td>Morphological features, Wavelet Transform</td>
<td>SVM</td>
<td>97.82%</td>
</tr>
<tr>
<td>Llamado et al. [33]</td>
<td>Wavelet Transform, Morphological features</td>
<td>LD</td>
<td>78.00%</td>
</tr>
<tr>
<td>Alvarado et al. [34]</td>
<td>Pulse based features</td>
<td>LD</td>
<td>93.60%</td>
</tr>
<tr>
<td>Ye et al. [35]</td>
<td>Interval Features, Wavelet Transform, ICA, PCA</td>
<td>SVM</td>
<td>86.40%</td>
</tr>
</tbody>
</table>
It is hard to compare the studies in a stable way, because of reasons such as the different number of subjects, different number of the arrhythmia types, different subjects, different databases and different classification types. High classification performances are reported in the literature. In this study, the efficiency of the DL algorithms has been proven with high classification performances of 95.05%, 93.87%, and 94.51% for accuracy, sensitivity, and selectivity, respectively.

IV. CONCLUSIONS

PQRST complexes and T waves plots a regular form in normal sinus rhythm. Any obvious changes occurring in the PQRS and T waves lines indicate the irregularity or arrhythmia in heartbeats. Since the determination of the features such as intervals, segment measurements, heart rate, and the frequency of R waves have great benefits for clinicians to identify the cardiac diseases and arrhythmias, the physiology and the morphology of the ECG waveforms have frequently been used in clinical trials [12], [14]. The meaningful data points for arrhythmia classification are thickened between S-T waves and P-Q waves for the proposed DBN-based multistage classification model.

The proposed DBN-based multistage arrhythmia classification has discriminated five types of heartbeats with a high accuracy rate of 95.05%. The achievements prove the success and efficiency of the DBN algorithm in raw ECG signals.

REFERENCES


EFFECTS OF SPECTRAL CLUSTERING ON DOCUMENT CATEGORIZATION USING DISTRIBUTED TOOLS

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Abstract—Amount of text data being generated each day is so huge that it is impossible to keep track of. Clustering text documents is an important task to make use of information carried by plain text. In many text document collections, clusters do not form easily separable compact shapes. Spectral clustering is an efficient when clustering such datasets because algorithm considers connectedness of clusters rather than assuming a specific statistical model and optimizing parameters of that model. On the other hand, distributed data processing tools have been becoming more and more widespread. Running clustering algorithms with distributed tools is getting essential in big data environments. In this research, spectral clustering is executed on text data using big data analysis tools. Effects of algorithm on document clustering is discussed with respect to cluster quality measures. Moreover, existing works about scalability of spectral clustering is investigated. Results show that spectral clustering algorithm categorizes documents more accurately than $k$-means. In experiments, text documents in 20-newsgroups are used as dataset, Apache Mahout is used as distributed machine learning library, Rand Index and Mutual Information measures are used to evaluate clustering performance.

Keywords: Text mining, document clustering, distributed systems, spectral clustering, big data

I. INTRODUCTION

As information technologies become more widespread in many aspects of the life, amount of data produced is growing gradually. Applications producing data includes both enterprise and public applications. Stock management, enterprise resource planning, customer relationship management applications are examples of enterprise applications. Social network applications, forums, news portals and blogs are examples of public applications. One of the most important common characteristics of these two separate software application groups is the fact that data produced using these applications should be stored and analysed. Storing data is important when auditing and tracking past transactions. Unless these are required, storing data without analysing is nothing other than wasting storage units of machines.

Most of content & service providers analyse data generated by users of systems they provide. For example, CRM application logs are analysed for segmentation or labelling of customer, user actions in an e-commerce application will be logged for promoting right product to right customer, social network application logs are analysed for providing people and content that are closely related to users, search engine logs are analysed for listing web pages relevant to search terms in an acceptable time amount.

Leading motivation behind collecting and analysing data is reaching a higher level of profit. Effective analysis of produced data enables marketing products in a more proactive way and governing customers effectively. Another purpose of analysis of data is enhancing performance of system. For example, in a search application, it is important to reduce search space and prevent search operation in whole data store. Many search engines crawl and index whole pages existing in world wide web. Performing a user search operation on a related subset of web document collection can provide a quicker search to user and less overhead to the vendor. This concern gets apparent in most of applications providing services using big data.

Recently, users of the software applications tend to search specific information with several keywords. They expect search system to be intelligent enough to examine requested information and fetch relevant results even data entities are not free text documents. Moreover, important part of the data produced by world consist of text documents such as news, blog posts, comments, product descriptions, and so on. Mining text data is important because of these facts.

In text mining, there are several issues where discussions are focused. First of all, converting text documents into vectors. It is necessary to express instances in dataset to run learning algorithms in data mining. Data contained by text documents consists of terms and number of terms in common text data sets are so high that they can be expressed with tens of thousands. Second issue is distance / similarity measure to use. It is important to choose distance best fitting to data domain in order to get better results. Another issue is algorithm to classify / cluster dataset. Characteristics of data domain and shape of data are important factors to determine algorithm.

This study focuses on clustering of text documents using spectral clustering algorithm [1], which is one of the effective methods for clusters that can hardly be separated linearly. It regards affinity matrix of data. Entries of this matrix are pairwise affinities between data instances. Algorithm is composed around eigenvectors of this matrix and has successful applications in image segmentation, that is another domain where clusters frequently do not seem in linearly separable compact shapes [2]. Moreover, in big data environments distribution of computation is usually required. Therefore, when clustering big datasets, accuracy of the used method is not sufficient alone. It must also scalable in
order to be applied for such datasets. Therefore, distributed tools are used in the work in scope of this study. Methods and algorithms are evaluated based parallel and distributed execution.

In section 2, previous work on spectral clustering and text mining is introduced. Then, in the 3rd section, spectral clustering algorithm is described in detail and some issues about how to apply algorithm are discussed. In section 4, experiments are explained including methods, used tools, dataset and experimental results. Then, final remarks, concluding words and possible future work are expressed in section 5.

II. RELATED WORK

Text document clustering is a main branch of data mining so there exist some surveys about it. M. W. Berry published an extensive survey of text clustering [3]. In that study, effective vectorization of text passages, dimensionality reduction methods and term-to-term similarities are mentioned. In the survey prepared by Sathiayakumari et al. [4], pros and cons of several clustering algorithms on text data are revealed and they are compared. In the study of Anna [8], similarity measures are compared using experiments on several data sets. Aggarwal and Zhao made a comprehensive study about issues that should be overcome in text clustering [10]. In that study, feature selection, dimensionality reduction and algorithm choice are discussed topics.

Spectral clustering algorithm is based on spectral graph theory. The theory includes analysis of graphs using eigenvectors of the matrix representing pairwise similarities of vertices in the graph. Spielman’s lecture notes are one of the resources explaining theory well [15]. On the usage of spectral clustering for text data, Vempala and Wang assert spectral projection enhances clustering results on document collections [5]. Their assertion is based on experimental results. Chen et al. address scalability problem of spectral clustering [11]. They offer methods for approximating dense similarity matrix and parallelize computations in spectral clustering. Chennubhotla and Jepson proposes a hierarchical algorithm for efficiently compute largest eigenvectors of large matrices [12]. A parallel eigensolver algorithm is proposed by Bientinesi et al. [13] and empirical success of their algorithm is expressed by comparing with other well-known eigensolver algorithms. Strakova and Gansterer introduce a distributed eigensolver [14]. Their proposed method considers only nearest neighbour similarities and is efficient in loosely coupled networks that are distributed arbitrarily.

As the notion of “big data” become more widespread, more studies about distributed tools and algorithms to process big datasets are being done. Judith and Jayakumari prepared a review about recent work on distributed document clustering algorithms [17]. In this study, existing distributed solutions are compared in terms of speed, accuracy, cluster quality and scalability. In another work done by Li et al. [18], distributed k-means algorithm executing on MapReduce model is evaluated. Possible enhancements approaches like partitioning dataset with an effective hashing algorithm, effective center initialization and pruning unnecessary distance calculations are mentioned in this paper. The article prepared by Datta et al. provides an overview of distributed data mining algorithms and applications in peer-to-peer networks [16].

III. SPECTRAL CLUSTERING ON TEXT DATA

A. Representing text data

Data instances are required to be expressed in vectors in learning applications. In text documents, data information is carried by terms. Therefore, as well as size of document vectors, algebraic value of entries in document vectors is determined by terms that occurs in documents. Basically, document $x$ can be converted to vectors as follows:

$$x = \{t_1 : tf_1, t_2 : tf_2, \ldots, t_d : tf_d\}$$

and where $x$ is vector representation of document, $t_i$s are terms falling into document $x$, and $tf_i$s are the frequency (number of occurrence) of $t_i$ in $x$. This vector is called term frequency vectors. A more advanced and more efficiently used vector model for text document is tf-idf model:

$$x = \{t_1 : w_1, t_2 : w_2, \ldots, t_d : w_d\}$$

and

$$w_i = \frac{|S|}{|\{x_j \in S | t_i \in x_j\}|}$$

where $S$ is data set, $x_i$s are documents in data set. This model is called tf-idf model. In this model, lower scores are assigned to terms that are not distinctive for document. This model is one of the most common techniques used to transform text documents into vectors. Derivation of tf-idf vectors from plain text is done by Apache Mahout’s seq2sparse utility tool [7].

Learning algorithm executions require a distance/similarity measure to cluster dataset into groups. When deciding distance measure characteristics of the dataset domain is an important factor. There is no global right distance measure but there are effective distance measures for data type. Cosine distance measure is one of the best fitting ones when working on text data so it is used in experiments of this study. With this measure, distance between two data instances $x_i$ and $x_j$ is calculated in following way:

$$d_{ij} = \frac{x_i \cdot x_j}{|x_i| \cdot |x_j|}$$

As the name implies, cosine distance $d_{ij}$ is equals to the cosine of the angle between two data vectors $x_i$ and $x_j$. Calculating affinity from distance is another issue. Calculation of cosine similarity between text documents is as follows:

$$a_{ij} = 1 - d_{ij}$$

where $d_{ij}$ is cosine distance.
B. Spectral Clustering Algorithm

Spectral clustering algorithm is an effective way of data clustering because it considers pairwise affinities of data instances without making any statistical model assumptions. When dataset is composed of complex-shaped connected clusters rather than compact clusters, ordinary clustering algorithms like k-means are hard to perform well.

In Figure 1, dataset represented in the left hand side is composed of compact clusters. Most intra-cluster pairwise distances in between instances of this dataset is lower than inter-cluster pairwise distances. Clusters seem like compact structures and instance density increases towards cluster center . However, in the dataset visualized in the left hand side, clusters are connected but not compact. They are formed with instances that are successively close to each other. In this case, data instances in same cluster are not necessarily closer to the each other than instances from different clusters. However, they are connected to each other with a chain of close instances falling into the same cluster. This two nested circular clusters are just for exemplifying but clusters may have more complex shapes than circles. In such cases, clustering algorithms that assume some model and try to optimize parameters of that model may easily fail to group data into clusters.

Spectral clustering algorithm considers only data instead of making assumptions based on some statistical models. It takes affinity matrix $A$ of the dataset as input and operates on top eigenvectors of the Laplacian matrix $L$ of affinity matrix $A$. Affinity matrix is as follows:

$$A^{n\times n} = \begin{bmatrix}
a_{11} & a_{12} & \ldots & a_{1n} \\
a_{21} & a_{22} & \ldots & a_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
a_{n1} & a_{n2} & \ldots & a_{nn}
\end{bmatrix}$$

where $n$ is number of instances in dataset $S$ and $a_{ij}$ is similarity between $x_i$ and $x_j$. Calculation of affinity is given in equation 5. When constructing affinity matrix, one approach is forming it by calculating all pairwise affinities and regarding dataset as a fully connected graph. In other words, each pairwise affinity is taken into consideration no matter it is strong or weak. In this case, each instance is assumed to be connected to every other instance. Another approach when creating affinity matrix is using a graph construction method. In that way, many weak connections between instances are pruned in order to relax calculation and promote strong local neighbourhoods. Two techniques are used for graph construction:

- $\epsilon$-neighbourhood graph: Affinity $d_{ij}$ between $x_i$ and $x_j$ is considered only if its value is higher than a predefined constant value $\epsilon$. Choosing parameter $\epsilon$ is important to determine which connections will exist and which will be pruned.
- k-nearest neighbourhood graph: For each data instance, connections to only k-nearest neighbours are considered. Other connections are ignored. Affinity matrix is created using k highest affinity values for each $x_i$.

Another issue in spectral clustering algorithm is calculation of graph Laplacian. When calculating Laplacian matrix, degree matrix is used besides affinity matrix. In fact, it is derived using affinity matrix. Degree matrix is a diagonal matrix whose $i^{th}$ diagonal entry is the sum of affinities calculated for instance $i$.

$$D^{n\times n} = \begin{bmatrix}D_{11} & 0 & \ldots & 0 \\
0 & D_{22} & \ldots & 0 \\
\vdots & \vdots & \ddots & \vdots \\
0 & 0 & \ldots & D_{nn}\end{bmatrix} \quad \text{(7)}$$

where

$$D_{ii} = \sum_{j=1}^{n} a_{ij} \quad \text{(8)}$$

There are two types of graph laplacians:

- Unnormalized Laplacian:

$$L = D - A \quad \text{(9)}$$

- Normalized Laplacian:

$$L = D^{-1/2} \cdot A \cdot D^{-1/2} \quad \text{(10)}$$

In our study, no graph construction method is used. Data is handled as fully connected graph. Then, spectral clustering algorithm is executed using normalized form of graph Laplacian matrix. Pseudocode is provided in algorithm 1 and [1] can be checked out for a more detailed explanation of spectral clustering.

Algorithm 1 Spectral Clustering

1: procedure CLUSTER-SPECTRAL($S$, $k$)
2: $A^{n\times n} \leftarrow$ affinity matrix of dataset $S$
3: $D^{n\times n} \leftarrow$ degree matrix of $A$
4: $L^{n\times n} \leftarrow D^{-1/2} \cdot A \cdot D^{-1/2}$
5: $E^{n\times k} = [e_1, e_2, \ldots e_k]$ (smallest k eigenvectors of L)
6: $Z^{n\times k} \leftarrow$ normalized form of $E$
7: cluster $Z$ into k clusters using k-means
8: assign each $x^i$ to corresponding cluster of $z^i$
9: return clusters
TABLE I Topics in 20-newsgroups dataset

<table>
<thead>
<tr>
<th>comp.graphics</th>
<th>rec.autos</th>
</tr>
</thead>
<tbody>
<tr>
<td>comp.os.ms-windows.misc</td>
<td>rec.motorcycles</td>
</tr>
<tr>
<td>comp.sys.ibm.pc.hardware</td>
<td>rec.sport.baseball</td>
</tr>
<tr>
<td>comp.sys.mac.hardware</td>
<td>rec.sport.hockey</td>
</tr>
<tr>
<td>comp.windows.x</td>
<td>sci.crypt</td>
</tr>
<tr>
<td>sci.electronics</td>
<td>talk.politics.misc</td>
</tr>
<tr>
<td>sci.med</td>
<td>talk.politics.guns</td>
</tr>
<tr>
<td>sci.space</td>
<td>talk.politics.mideast</td>
</tr>
<tr>
<td>talk.religion.misc</td>
<td>alt.atheism</td>
</tr>
<tr>
<td>alt.atheism</td>
<td>misc.forsale</td>
</tr>
<tr>
<td>soc.religion.christian</td>
<td></td>
</tr>
</tbody>
</table>

IV. EXPERIMENTS

A. Dataset

20-newsgroups dataset hosted by UCI Machine Learning Repository [6] is used in tests executions. It contains 18846 documents of 20 different groups. There are 93,560 distinct terms in dataset. No NLP method such as stemming or stop-word elimination is used. In other words, "play" and "playing" are accepted different terms for our algorithm. Topics in 20-newsgroups dataset are listed in Table I.

B. Tools Used

Apache Hadoops distributed file system is used for storing data and MapReduce is used for processing data. MapReduce is a distributed processing model that fits into many real world problems [9]. Hadoop is one of the most common scalable MapReduce vendors and it has proven success in many real time systems. Hadoop is run in pseudo-distributed mode in our experiments.

Machine learning library used in experiments is Apache Mahout [7]. It works on top of Hadoop. Machine learning tasks are submitted by Mahout to Hadoop and they are executed as MapReduce jobs. Mahout does not only provide machine learning algorithms but also perform some utility tasks such as creating tf-idf vectors from plain text documents or calculating distance between vectors.

C. Experimental Results

As stated earlier, k-means and spectral clustering algorithms are executed to cluster 20-newsgroup dataset in scope of experiments in this research. Experiments are run 10 times consecutively using Mahout’s command line interface. Some parameters passed required to clustering commands are as follows:

- convergence delta : 0.001
- max. number of iterations : 100
- initial clustering : Canopy
- distance measure : Cosine
- num. of clusters : 20

After executions of clustering algorithms, found cluster results are evaluated in terms of two cluster quality measures : adjusted rand index and adjusted mutual information.

Fig. 2 Adjusted Rand Index and Adjusted Mutual Information scores of k-means and spectral clustering algorithms

Figure 2 shows clustering results of k-means and spectral clustering algorithms. Spectral clustering apparently performs better than k-means algorithm in seen in the figure. Enhancement of score is obvious for both adjusted rand index and adjusted mutual information measures. Then, it can be said that spectral clustering has a more accurate clustering result on text data than k-means.

V. CONCLUSION AND FUTURE WORK

Clustering text documents is an important because text data constitutes an important part of the data produced each day. When running learning algorithms, data sets may not be easily separable. Text document collections usually exist in hardly-separable forms. In scope of this study, we focus our effort to apply spectral clustering algorithm on text data. Effects of spectral clustering algorithm observed on 20-newsgroups data set. Results show that accuracy of the spectral clustering algorithm is better compared to k-means. Solutions are prepared using distributed tools in order to make use it in big data problems.

For future work, a dimensionality reduction technique may be applied in order to get rid of high number of features in tf-idf vector form. Another enhancement may be using a graph construction method in order to prune unnecessary distance and affinity calculations. Experiments in this study are done without using any graph construction method.

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The Classification of White Wine and Red Wine according to their Physicochemical Qualities

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Abstract—The main purpose of this study is to predict wine quality based on physicochemical data. In this study, two large separate data sets which were taken from UC Irvine Machine Learning Repository were used. These data sets contain 1599 instances for red wine and 4898 instances for white wine with 11 features of physicochemical data such as alcohol, chlorides, density, total sulfur dioxide, free sulfur dioxide, residual sugar, and pH. First, the instances were successfully classified as red wine and white wine with the accuracy of 99.5229% by using Random Forests Algorithm. Then, the following three different data mining algorithms were used to classify the quality of both red wine and white wine: k-nearest-neighbourhood, random forests and support vector machines. There are 6 quality classes of red wine and 7 quality classes of white wine. The most successful classification was obtained by using Random Forests Algorithm. In this study, it is also observed that the use of principal component analysis in the feature selection increases the success rate of classification in Random Forests Algorithm.

Keywords—Classification, Random Forests, Support Vector Machines, k-Nearest-Neighbourhood.

I. INTRODUCTION

Today, varied consumers enjoy wine more and more. Wine industry is researching new technologies for both wine making and selling processes in order to back up this growth [1].

Physicochemical and sensory tests are used for evaluating wine certification [2]. The discrimination of wines is not an easy process owing to the complexity and heterogeneity of its headspace. The classification of wines is very important because of different reasons. These reasons are economic value of wine products, to protect and assure the quality of wines, to forbid adulteration of wines, and to control beverage processing [3].

Data mining technologies have been applied to classification of wine quality. The aim of machine learning methods similar to other applications is to create models from data to predict wine quality.

In the year of 1991, a “Wine” data set which contains 178 instances with measurements of 13 different chemical constituents such as alcohol, magnesium was donated into UCI repository to classify three cultivars from Italy [4]. For new data mining classifiers this data set has been majorly used as a benchmark because it is very easy to discriminate. For wine classification according to geographical region; principal component analysis (PCA) was carried out and reported [5]. The data they used in their study includes 33 Greek wines with physicochemical variables. Another work of wine classification depended on the physicochemical information. This information involved in wine aroma chromatograms as measured with a Fast GC Analyser [6]. In the latter study, three classification methods such as Linear Discriminant Analysis, Radial Basis Function Neural Networks and Support Vector Machines (SVM) are compared according to their performance in a two-staged architecture.

Some have proposed a few applications of data mining techniques to wine quality assessment. Cortez et al. [1] proposed a taste prediction technique. Their taste prediction technique, a support vector machine, multiple regression, and a neural network were applied to chemical analysis of wines. Shanmuganathan’s technique was about prediction the effects of season and climate on wine yields and wine quality [7]. The Wineinformatics system according to Chen et al. [8] idealized the flavor and characteristics of wine from natural-language reviews. They used hierarchical clustering and association rules.

II. MATERIALS AND METHODS

A. Wine Data

The data set is a wine quality dataset that is publicly available for research purposes from https://archive.ics.uci.edu/ml/datasets/Wine+Quality [9]. Both dataset contains 1599 instances with 11 features for red wine and 4898 instances and the same 11 features for white wine. The inputs include objective tests (e.g., PH values) and the output is based on sensory data (median of at least 3 evaluations made by wine experts). Each expert graded the wine quality between 0 (very bad) and 10 (very excellent). The two datasets are related to red and white variants of the Portuguese “Vinho Verde” wine.

The features include fixed acidity, volatile acidity, citric acid, residual sugar, chlorides, free sulfur dioxide, total sulfur dioxide, density, pH, sulphates, and alcohol. pH describes how acidic or basic a wine is on a scale from 0 (very acidic) to 14 (very basic). Most wines are between 3-4 on the pH scale. Chloride is the amount of salt in the wine. Alcohol is the percent alcohol content of the wine.

The goal of the data set is to predict the rating that an expert will give to a wine sample, using a range of physicochemical properties, such as acidity and alcohol composition. Due to privacy and logistic issues, only physicochemical (inputs) and sensory (the output) variables are available (e.g. There is no data about grape types, wine brand, wine selling price, etc.).
Table I and Table II present the 11 different physicochemical properties and data statistics (minimum, maximum, mean, and standard deviation values of all instances for each feature) of white wine and red wine sets respectively.

<table>
<thead>
<tr>
<th>Attribute (units)</th>
<th>White Wine</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed acidity (g/tartaric acid/dm³)</td>
<td>3.80</td>
<td>14.20</td>
<td>6.855</td>
<td>0.844</td>
<td></td>
</tr>
<tr>
<td>Volatile acidity (g/acetic acid/dm³)</td>
<td>0.080</td>
<td>1.100</td>
<td>0.278</td>
<td>0.101</td>
<td></td>
</tr>
<tr>
<td>Citric acid (g/dm³)</td>
<td>0.000</td>
<td>1.660</td>
<td>0.334</td>
<td>0.121</td>
<td></td>
</tr>
<tr>
<td>Residual sugar (g/dm³)</td>
<td>0.600</td>
<td>65.80</td>
<td>6.391</td>
<td>5.072</td>
<td></td>
</tr>
<tr>
<td>Chlorides (g/sodium chloride/dm³)</td>
<td>0.009</td>
<td>0.346</td>
<td>0.046</td>
<td>0.022</td>
<td></td>
</tr>
<tr>
<td>Free sulfur dioxide (mg/dm³)</td>
<td>2.000</td>
<td>289.0</td>
<td>35.31</td>
<td>17.01</td>
<td></td>
</tr>
<tr>
<td>Total sulfur dioxide (mg/dm³)</td>
<td>9.000</td>
<td>440.0</td>
<td>138.4</td>
<td>42.50</td>
<td></td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>0.987</td>
<td>1.039</td>
<td>0.994</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>2.720</td>
<td>3.820</td>
<td>3.188</td>
<td>0.151</td>
<td></td>
</tr>
<tr>
<td>Sulphates (g/potassium sulphate/dm³)</td>
<td>0.220</td>
<td>1.080</td>
<td>0.490</td>
<td>0.114</td>
<td></td>
</tr>
<tr>
<td>Alcohol (% vol)</td>
<td>8.000</td>
<td>14.20</td>
<td>10.51</td>
<td>1.231</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE II**

<table>
<thead>
<tr>
<th>Attribute (units)</th>
<th>Red Wine</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>StDev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed acidity (g/tartaric acid/dm³)</td>
<td>4.600</td>
<td>15.90</td>
<td>8.320</td>
<td>1.741</td>
<td></td>
</tr>
<tr>
<td>Volatile acidity (g/acetic acid/dm³)</td>
<td>0.120</td>
<td>1.580</td>
<td>0.528</td>
<td>0.179</td>
<td></td>
</tr>
<tr>
<td>Citric acid (g/dm³)</td>
<td>0.000</td>
<td>1.000</td>
<td>0.271</td>
<td>0.195</td>
<td></td>
</tr>
<tr>
<td>Residual sugar (g/dm³)</td>
<td>0.900</td>
<td>15.50</td>
<td>2.539</td>
<td>1.410</td>
<td></td>
</tr>
<tr>
<td>Chlorides (g/sodium chloride/dm³)</td>
<td>0.012</td>
<td>0.611</td>
<td>0.087</td>
<td>0.047</td>
<td></td>
</tr>
<tr>
<td>Free sulfur dioxide (mg/dm³)</td>
<td>1.000</td>
<td>72.00</td>
<td>15.87</td>
<td>10.46</td>
<td></td>
</tr>
<tr>
<td>Total sulfur dioxide (mg/dm³)</td>
<td>6.000</td>
<td>289.0</td>
<td>46.47</td>
<td>32.89</td>
<td></td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>0.990</td>
<td>1.004</td>
<td>0.997</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>2.740</td>
<td>4.010</td>
<td>3.311</td>
<td>0.154</td>
<td></td>
</tr>
<tr>
<td>Sulphates (g/potassium sulphate/dm³)</td>
<td>0.330</td>
<td>2.000</td>
<td>0.658</td>
<td>0.170</td>
<td></td>
</tr>
<tr>
<td>Alcohol (% vol)</td>
<td>8.400</td>
<td>14.90</td>
<td>10.42</td>
<td>1.066</td>
<td></td>
</tr>
</tbody>
</table>

**B. Data Mining Approach**

To evaluate performance of selected tool using the given dataset, several experiments are conducted. For evaluation purpose, two test modes are used, the k-fold cross-validation (k-fold cv) mode, and percentage split (holdout) method.

The k-fold cv refers to a widely used experimental testing procedure where the database is randomly divided into k disjoint blocks of objects, then the data mining algorithm is trained using k-1 blocks and the remaining block is used to test the performance of the algorithm, this process repeated k times. At the end, the average value of the recorded measurement is found [10]. It is common to choose k as 10.

In percentage split mode, the database is randomly divided into two disjoint datasets. The first set, which the data mining system tries to extract knowledge from called training set. The extracted knowledge may be tested against the second set which is called testing set [10].

In this study, for k-fold cross-validation mode, different k values are tested for each method. The best classification results of each method are obtained when k value is chosen as 10.

Firstly, both datasets are separated into training and testing set by using 10-fold cross-validation method. Afterwards, both datasets are randomly divided into two groups called training and testing set. First set involves randomly 80% of dataset, and the other set involves the resting data.

**C. Data Mining Techniques**

In the original form of this datasets, two datasets were created, using red and white wine samples. The two datasets are related to red and white variants of the Portuguese “Vinho Verde” wine.

First, these two datasets have been combined into one dataset to classify wine samples as red wine and white wine. Three different data mining algorithms were used in our study. Those classification algorithms applied on the data set are k-nearest-neighbourhood (k-NN), random forests (RF), and support vector machines.

1) **k-Nearest-Neighbourhood Classifiers:** This method was depicted in the beginning of 1950s. Nearest-neighbourhood classifiers are depended on learning by analogy, this means a comparison between a test tuple with similar training tuples. The training tuples are described by n attributes. Each tuple corresponds a point in an n-dimensional space. All the training tuples are stocked in an n-dimensional pattern space. For an unknown tuple, a k-nearest-neighbourhood classifier searches the pattern space for the k training tuples that are closest to the unknown tuple. k training tuples are called as the k “nearest neighbours” of the unknown tuple [11].

“Closeness” is a metric distance, likewise Euclidean distance. The Euclidean distance between two points or tuples, say, X₁=(x₁₁, x₁₂, …, x₁n) and X₂=(x₂₁, x₂₂, …, x₂n), is

\[
\text{dist}(X₁, X₂) = \sqrt{\sum_{i=1}^{n} (x₁ᵢ - x₂ᵢ)^2}.
\]

2) **Random Forests:** This methodology uses a combination of tree predictors; each individual tree depends on a random vector. This random vector has identical and alike distribution for all trees in the forest. It was described by Breiman in 2001[12].

3) **Support Vector Machines:** This method was derived from statistical learning theory by Vapnik and Chervonenkis. It was first introduced in 1992 by Boser, Guyon, and Vapnik. This method is used for the classification of both linear and nonlinear data. It uses a nonlinear mapping to transform the original training data into a higher dimension. It searches for the linear optimal separating hyperplane in this new dimension. A hyperplane can separate data from two classes, with a suitable nonlinear mapping to sufficiently high dimension. The SVM uses support vectors and margins to find this hyperplane [11].

Then, the following three different data mining algorithms were used to classify the quality of both red and white wine samples: k-nearest-neighbourhood, random forests, and support vector machines.

Afterwards, principal component analysis in the feature selection was applied to the original both red wine dataset and white wine dataset for each method. Three data mining algorithms were used to classify the quality of both red wine samples and white wine samples.
III. EXPERIMENTAL RESULTS

In this study, firstly three classification algorithms were used to classify the wine samples as red wine and white wine. A model was built using each method and applied to the wine data set. The classification results of the three classification algorithms are evaluated both test modes which are 10-fold cross-validation, and 80% percentage split.

Also, some of the standard performance measures (statistics) are calculated to evaluate the performance of the algorithms. The standard performance measures are recall, precision, F measure, and ROC values.

Table III presents the correctly classified instances results of the classification of red and white wine samples.

<table>
<thead>
<tr>
<th>Test Modes</th>
<th>Classifier</th>
<th>Precision (%)</th>
<th>Recall (%)</th>
<th>F Measure (%)</th>
<th>ROC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross</td>
<td>SVM</td>
<td>99.1</td>
<td>99.1</td>
<td>98.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>k-NN</td>
<td>99.2</td>
<td>99.2</td>
<td>99.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>99.5</td>
<td>99.5</td>
<td>99.8</td>
<td></td>
</tr>
<tr>
<td>Percentage</td>
<td>SVM</td>
<td>99.2</td>
<td>99.2</td>
<td>98.6</td>
<td></td>
</tr>
<tr>
<td>Split</td>
<td>k-NN</td>
<td>99.2</td>
<td>99.2</td>
<td>98.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>99.5</td>
<td>99.5</td>
<td>99.9</td>
<td></td>
</tr>
</tbody>
</table>

The most successful classification result of red and white wine samples was obtained by Random Forests Algorithm for both test modes. The accuracy of each cross-validation and percentage split mode with this algorithm is 99.5229%, and 99.4611% respectively.

Table III clearly shows that Random Forests algorithm outperforms from the other algorithms in two test modes.

Secondly, for the classification of the quality of both red and white wine samples, the classification experiment is measured by the accuracy percentage of classifying the instances correctly into its class according to quality features which are ranged between 0 (very bad) and 10 (very excellent) as 11 different classes and totally 22 classes.

Table IV and Table V present the correctly classified instances results of the classification of white wine sample qualities respectively.

For k-nearest-neighbourhood classifiers, different k values are tested for each test mode. When k value is increased, the achievement of the classification decreases. For this reason, k value is taken as 1.

### TABLE IV

<table>
<thead>
<tr>
<th>Test Modes</th>
<th>Classifier</th>
<th>Precision (%)</th>
<th>Recall (%)</th>
<th>F Measure (%)</th>
<th>ROC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross</td>
<td>SVM</td>
<td>39.6</td>
<td>52.1</td>
<td>44.1</td>
<td>66.7</td>
</tr>
<tr>
<td></td>
<td>k-NN</td>
<td>65.1</td>
<td>65.4</td>
<td>65.2</td>
<td>75.0</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>71.0</td>
<td>70.4</td>
<td>69.5</td>
<td>87.3</td>
</tr>
<tr>
<td>Percentage</td>
<td>SVM</td>
<td>39.4</td>
<td>51.2</td>
<td>43.7</td>
<td>65.8</td>
</tr>
<tr>
<td>Split</td>
<td>k-NN</td>
<td>63.0</td>
<td>63.3</td>
<td>63.0</td>
<td>73.1</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>69.8</td>
<td>68.7</td>
<td>67.4</td>
<td>85.7</td>
</tr>
</tbody>
</table>

The most successful classification result of white wine sample qualities as 11 classes was obtained by using Random Forest algorithm for both test modes. The accuracy of each cross-validation and percentage split mode with this algorithm is 70.3757%, and 68.6735% respectively.

The most successful classification result of red wine sample qualities as 11 classes was obtained by using Random Forest algorithm for both test modes. The accuracy of each cross-validation and percentage split mode with this algorithm is 69.606%, and 71.875% respectively.

Finally, for increasing of classification success in this study, the number of features was reduced by using PCA algorithm and the process wine quality classification was repeated by using SVM, k-NN, and RF algorithms.

Table VI and Table VII present the correctly classified instances results of the classification of white and red wine sample qualities after applying PCA respectively.

### TABLE V

<table>
<thead>
<tr>
<th>Test Modes</th>
<th>Classifier</th>
<th>Precision (%)</th>
<th>Recall (%)</th>
<th>F Measure (%)</th>
<th>ROC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross</td>
<td>SVM</td>
<td>48.1</td>
<td>58.3</td>
<td>52.7</td>
<td>70.6</td>
</tr>
<tr>
<td></td>
<td>k-NN</td>
<td>64.3</td>
<td>64.8</td>
<td>64.5</td>
<td>72.7</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>66.8</td>
<td>69.6</td>
<td>67.8</td>
<td>86.4</td>
</tr>
<tr>
<td>Percentage</td>
<td>SVM</td>
<td>49.7</td>
<td>59.1</td>
<td>53.9</td>
<td>70.8</td>
</tr>
<tr>
<td>Split</td>
<td>k-NN</td>
<td>65.6</td>
<td>65.6</td>
<td>65.5</td>
<td>72.8</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>69.6</td>
<td>71.9</td>
<td>70.5</td>
<td>87.2</td>
</tr>
</tbody>
</table>

### TABLE VI

<table>
<thead>
<tr>
<th>Test Modes</th>
<th>Classifier</th>
<th>Precision (%)</th>
<th>Recall (%)</th>
<th>F Measure (%)</th>
<th>ROC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross</td>
<td>SVM</td>
<td>39.8</td>
<td>52.2</td>
<td>44.0</td>
<td>66.3</td>
</tr>
<tr>
<td></td>
<td>k-NN</td>
<td>64.5</td>
<td>64.7</td>
<td>64.6</td>
<td>74.4</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>70.7</td>
<td>69.9</td>
<td>68.8</td>
<td>86.9</td>
</tr>
<tr>
<td>Percentage</td>
<td>SVM</td>
<td>39.4</td>
<td>51.2</td>
<td>43.6</td>
<td>65.9</td>
</tr>
<tr>
<td>Split</td>
<td>k-NN</td>
<td>63.5</td>
<td>63.6</td>
<td>63.5</td>
<td>73.7</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>68.1</td>
<td>67.4</td>
<td>66.3</td>
<td>85.4</td>
</tr>
</tbody>
</table>

### TABLE VII

<table>
<thead>
<tr>
<th>Test Modes</th>
<th>Classifier</th>
<th>Precision (%)</th>
<th>Recall (%)</th>
<th>F Measure (%)</th>
<th>ROC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross</td>
<td>SVM</td>
<td>47.8</td>
<td>58.0</td>
<td>52.4</td>
<td>69.7</td>
</tr>
<tr>
<td></td>
<td>k-NN</td>
<td>64.3</td>
<td>64.8</td>
<td>64.5</td>
<td>72.7</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>68.4</td>
<td>71.2</td>
<td>69.4</td>
<td>86.4</td>
</tr>
<tr>
<td>Percentage</td>
<td>SVM</td>
<td>47.8</td>
<td>56.9</td>
<td>51.9</td>
<td>69.3</td>
</tr>
<tr>
<td>Split</td>
<td>k-NN</td>
<td>68.0</td>
<td>67.8</td>
<td>67.8</td>
<td>74.4</td>
</tr>
<tr>
<td></td>
<td>RF</td>
<td>71.4</td>
<td>73.4</td>
<td>72.1</td>
<td>87.8</td>
</tr>
</tbody>
</table>

The most successful classification result of white wine sample qualities after applying PCA was obtained by using Random Forest algorithm for both test modes. The accuracy of each cross-validation and percentage split mode with this algorithm is 69.9061%, and 67.449% respectively.
The most successful classification result of red wine sample qualities after applying PCA was obtained by using Random Forest algorithm for both test modes. The accuracy of each cross-validation and percentage split mode with this algorithm is 71.232%, and 73.4375% respectively.

IV. CONCLUSIONS

For each classification model, we analyzed how the results vary whenever test mode is changed. The study includes the analysis of classifiers on both red and white wine data set. The results are described in percentage of correctly classified instances, precision, recall, F measure, and ROC after applying the cross-validation or percentage split mode.

Different classifiers like k-nearest-neighborhood, random forests, and support vector machines are evaluated on datasets.

Results from the experiments lead us to conclude that Random Forests Algorithm performs better in classification task as compared against the support vector machine, and k-nearest-neighbourhood.

After applying PCA, the success rate of quality classification for white wine has decreased from 70.3757% to 69.9061% for cross validation mode. The success rate of quality classification for white wine has decreased from 68.6735% to 67.449% for percentage split mode.

After applying PCA, the success rate of quality classification for red wine has increased from 69.606% to 71.232% for cross validation mode. The success rate of quality classification for red wine samples has increased from 71.875% to 73.4375% for percentage split mode.

REFERENCES


Establishment of Fiber Optic Cabling System In Kirkuk City By Using Ant Colony Optimization And Genetic Algorithm

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Abstract: Connection-oriented network routing (CONR) is one of the NP-hard problems. In the recent years, to solve the problem of CONR it was using the heuristic methods such as minimum spanning tree methods (Kruskal and Prim Algorithms) and shortest path methods (A Star and Dijkstra Algorithms) and also metaheuristic methods (Ant Colony Optimization (ACO), Genetic Algorithm (GA) and Artificial Bee Colony (ABC)). But as the complexity of the problem increase, the guarantee to achieve the best results by heuristic algorithms decreases. Therefore, in large scale problems metaheuristic algorithms are preferred. In this study, it was applied CONR to provide internet and telephone lines for Kirkuk city and the near regions in Iraqi by using the fiber optical systems. Firstly, the locations of 56 fiber optic panels previously determined with particle swarm intelligence algorithm (PSO) are placed Kirkuk city. Then, it was aimed to wire all the panels by fiber optic cables in minimum cost, to raise the data transfer speed, to decrease the excavation process. As a result, two different metaheuristic algorithms (ACO and GA) were applied to achieve these targets and compared the results of them. After the experiments, the optimum distance between the panels were obtained with ACO and GA as 366100 km and 353400 km, respectively. The results show that GA is the best optimization algorithm for this problem.

Keywords— Connection-oriented network routing, Ant Colony Optimization, Genetic Algorithm, fiber optical systems, CONR

I. INTRODUCTION

When transmitting data through a network from one source to another the data follows a special path. In its way towards the target area the data passes through a chain of panels, this process is called network routing [1,2].

Whether the distribution path is reasonable, it has large impact on speed, cost and effectiveness in the logistics system, so it is very important to use a reasonable method to determine a reasonable distribution route. The exact solution is very difficult to study due to the NP-Hard nature of the problem, so heuristics may well be a viable direction [1,2]. One of the NP-hard problems is connection-oriented network routing (CONR).

In literature, different researchers dealt with the subjects of network routing and finding the shortest route. These researchers applied different kinds of heuristic algorithms and metaheuristic algorithms to solve the problem of CONR. Karakas [1] applied Dijkstra and Prim Algorithms to decrease the cost of creating network across Turkey to the half. Hardi [2] used the Genetic Algorithms (GA) to determine the shortest route that could be followed by the mineral water company in order to enable the distributors to get to their destinations through the shortest distance of all available paths. Mahia et al. [3] proposed new hybrid method to optimize parameters that affect performance of the ACO algorithm using Particle Swarm Optimization (PSO). PSO is preferred to detect optimum values of parameters which are used for city selection operations in the ACO algorithm and determines significance of inter-city pheromones and distances. Experimental results showed that the performance of proposed method by using fewer ants than the number of cities for the TSPs was better than the performance of compared methods in most cases in terms of solution quality and robustness. Kuzu et al. [4] used eight of the most common kinds of metaheuristic algorithms to solve the TSP problem which is considered one of the NP-hard problems. Dikmen et al. [5] applied the artificial intelligence techniques to solve the travelling salesman problem (TSP) in order to find the shortest ways to connect the Turkish cities. The results showed that the ACO method is better than the GA concerning the distance and time. Fong and Yuan [6] applied ACO to solve the TSP problem and reached the best results of network routing solution. İşçi and Korukoğlu [7] applied heuristic algorithms (prim & kruskal) and metaheuristic algorithm (GA) to decrease the cost of connecting network cables. The results showed that GA is better than prim & kruskal concerning this issue [7]. Kaya [8] applied Minimum spanning tree algorithms (Floyd & kruskal) to find the shortest path to provide gas pipeline to a particular area.

In this study, it was proposed CONR to provide internet and telephone lines for Kirkuk city and its near region in Iraqi using the fiber optical systems. The CONR consists a number of Panels, where each pair of panels has a definite distance. The purpose of this study is to visit all the panels such that the
total distance will be minimized. Also, it was aimed to wire all the panels by fiber optic cables in minimum cost, to raise the data transfer speed and to decrease the excavation process. As a result, two different metaheuristic algorithms, ACO and GA, were applied to achieve these targets and compared the results of them.

II. MATERIAL AND METHODS

A. Problem Description

In this study, connection-oriented network routing application will be made in order to minimize the cost of providing internet and landline telephone services to 9679 sq. km of Kirkuk city and its nearby regions in Iraq by using the fiber optical systems. The advantage of using fiber optical system is to increase the speed of transmission data. The panels were distributed in the city using PSO taking into consideration the required conditions. The locations of 56 panels are shown in Fig. 1.

![Fig. 1. Locations of panels in Kirkuk city](image)

The (graph theory) has been used to determine the distances between the panels. If it is assumed that each panel is a node and each fiber optic cable is an edge, then all the panels connected by fiber optical cables will form the following graph in Fig. 2. Each node has its direct path with the other nodes on condition of passing once from each one. In telecommunication science, this is called Hamiltonian path. Fig. 2 represents the fiber optics panels in the shape of a completed graph.

![Fig. 2. Fiber optics panels in the shape of a completed graph](image)

In order to solve this problem, it was determined the distances between these panels in a two-dimensional matrix as shown in Table 1, firstly.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>256</td>
<td>104</td>
<td>76</td>
<td>123</td>
<td>135</td>
<td>83</td>
<td>75</td>
<td>98</td>
<td>113</td>
<td>110</td>
<td>82</td>
<td>93</td>
<td>123</td>
<td>145</td>
<td>131</td>
<td>104</td>
<td>76</td>
<td>123</td>
<td>135</td>
<td>83</td>
</tr>
</tbody>
</table>

B. Ant Colony Optimization Algorithm (ACO) For CONR

The ACO algorithm was developed by Dorigo et al [9]. This algorithm is inspired by the actual ant colony behaviors. By examine behaviors of ants in real life, it is observed that ants have the ability to find the shortest path between their nest and food source [9]. The most important issue in finding the shortest path is the ephemeral, chemical matter of pheromone that ants leave on the path they use. Ants in a colony usually choose a path where pheromone matter is concentrated. The amount of pheromone increases on a frequently used route [10]. The ACO algorithm suggests a solution for the CONR problem. The solution aims to form a closed tour of minimum length with the condition of visiting every panel at once. In this study, it is accepted that ants leave pheromones on inter-panel routes that they use and this pheromone becomes ephemeral in a certain ration. Selection of the panels to which ants will go is performed depending on the distance and the amount of pheromones between panels. This algorithm is operated iteratively and the shortest route found is regarded as the best solution. Selection of panel j, to which an ant in panel i in iteration t will go, is made according to Eq. (1) [3].

$$O_{t}(i,j) = \frac{(\tau(i,j))^\alpha \times (\eta(i,j))^\beta}{\sum_{m \in N(i)} (\tau(i,m))^\alpha \times (\eta(i,m))^\beta} \quad \text{when } j \in V_t(i) \quad (1)$$

In Eq. (3), $\tau(i,j)$ represents the amount of pheromones between i and j panel, $n_ij$ represents information (1/dij) pertaining to distance between i and j panel, and j display panel where kth ant can go. An ant chooses the panel with the highest ratio of $O_{k}(i,j)$ by making a greedy selection. Parameters $\alpha$ and $\beta$ are used for determining the importance between amount of pheromones and distance inter-panel. kth ant completes one total tour by using Eq. (1). The above mentioned operation is repeated in t iteration for all ants that are present in the colony [3]. The amount of pheromones left by an ant on a path that it has used is determined according to Eq. (2).
\[
\Delta \tau^k_i(t, t + 1) = \begin{cases} 
\frac{Q}{\sum_{r \in R^k} \tau^r_i}, & \text{if} (i, j) \text{ route performed by the } k \text{th ant} \\
0, & \text{otherwise}
\end{cases} 
\]

Where \( L^k \) represents distance of tour, \( Q \) represents a constant number and \( k \) represents \( k \th \) ant in the colony. Total amount of pheromones that ants, which are present in colony and use the path between panel \( i \) and \( j \) have left, is calculated by using Eq. (3).

\[
\Delta \tau^k_i(t, t + 1) = \sum_{t=1}^{n} \Delta \tau^k_i(t, t + 1) 
\]

Amount of pheromones, which will be found in inter-panel routes in iteration \((t+1)\), is determined as in Eq. (4) depending on the impact of evaporation as well.

\[
\tau_{ij}(t + 1) = \sum_{t=1}^{n} (1 + p)\tau_{ij}(t) + \Delta \tau^k_i(t, t + 1) 
\]

In Eq. (4), \( P \) is the degree of evaporation and receives a value at intervals \([0–1]\). When the maximum number of iterations is reached, the shortest tour length obtained is considered as the solution of the problem \([3]\).

C. Genetic Algorithm (GA) For CONR

- Coding and structure of a chromosome

In this study, it was used a code of some sort of permutation type. Fig. 3 was given as an example of the structure of a chromosome composed for 8 panels. It explains the idea of finding the cheapest round-trip tour a fiber optic cable has to take by starting from the center panel and visiting all the 8 panels.

![Fig. 3. Structure of a chromosome](image)

- The initial population generation

When composing the initial population generation for CONR problem, there are 57 genes for each chromosome and this number differs from one problem to another. These 56 genes represent one chromosome and each chromosome is considered as path for the fiber optical cable.

- Fitness Function

The fitness function could be applied to find optimum solution for solving the CONR Problem according to the following Eq.(5).

\[
\text{Min} = \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} \times X_{ij} 
\]

The fitness function that characterizes each chromosome represents the total length of the route from the center panel to the last panel (gene) moving according to the order of the genes in the chromosome. The best chromosome is the one gives the minimum value of fitness \([11,12]\).

- Selection

The Roulette-Wheel method is applied to select the best parent in the CONR problem. In this method each individual is assigned a slice of a circular “roulette wheel”, the size of the slice being proportional to the individual’s fitness. The wheel is spun \( N \) times, where \( N \) is number of individuals in the population. On each spin, the individual under the wheel’s marker is selected to be in the pool of parents for the next generation\([11,13]\).

- Crossover Operation

Crossover is considered one of the effective elements in the performance of GA. The aim of this operation is to choose good parents (chromosomes with high-value) in order to create children chromosomes (with bigger-value). In CONR problem, the fiber optic cables were required to pass once from every panel. In order to avoid repeating the passage through the same panel, the one cut crossover type is preferred. Fig. 4 represents the example of crossover operation for CONR with 8 panels\([11,14]\).

![Fig. 4. Crossover Operation](image)

- Mutation Operator

Mutation operator is also considered of the effective elements in the performance of GA. The aim of mutation operator is maintaining the diversity within the chromosome that exists in the population. The mutation operator cannot be applied on all children (chromosomes), but only on a small percentage of them. In CONR problem, the mutation operator will swap the places of the panels in a single chromosome in random form\([11,14]\).

- Forming New Generation

According to the results on fitness function, the new population is compared with the previous population after selecting the initial population generation, selecting parent,
The obtained results from GA and ACO algorithms were shown in Table 4 and Table 5.

### III. RESULTS AND DISCUSSION

In this study, it was investigated CONR problem with minimum cost and excavation process and maximum speed to provide internet and telephone lines for Kirkuk city and the near regions in Iraqi using GA and ACO algorithms and the results of these algorithms were compared. To solve the Kirkuk’s CONR problem, the C#2013 platform was preferred for programming GA and ACO.

The number of iteration was selected as 3000 times for both GA and ACO. Other parameter values for ACO and GA were given in Table 2 and Table 3, respectively.

The obtained results from GA and ACO algorithms were showed in Table 4 and Table 5.

#### TABLE 2. PARAMETER VALUES FOR ACO

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ants</td>
<td>56</td>
</tr>
<tr>
<td>Pheromone relatively importance</td>
<td>1</td>
</tr>
<tr>
<td>Relative importance of heuristic factor</td>
<td>3</td>
</tr>
<tr>
<td>Pheromone evaporation coefficient</td>
<td>0.1</td>
</tr>
</tbody>
</table>

#### TABLE 3. PARAMETERS VALUES FOR (GA)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population size</td>
<td>3000</td>
</tr>
<tr>
<td>Selection strategy</td>
<td>Roulette Wheel Selection</td>
</tr>
<tr>
<td>Crossover percentage on population</td>
<td>0.7</td>
</tr>
<tr>
<td>Mutation percentage on population</td>
<td>0.1</td>
</tr>
</tbody>
</table>

#### TABLE 4. RESULTS OBTAINED FROM ACO ALGORITHM.

<table>
<thead>
<tr>
<th>Search Information</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of iteration</td>
<td>3000</td>
</tr>
<tr>
<td>Found route distance</td>
<td>366100</td>
</tr>
<tr>
<td>Shortest route</td>
<td></td>
</tr>
</tbody>
</table>

#### TABLE 5. RESULTS OBTAINED FROM (GA) ALGORITHM.

<table>
<thead>
<tr>
<th>Search Information</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of iteration</td>
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</tr>
<tr>
<td>Found route distance</td>
<td>353400</td>
</tr>
<tr>
<td>Shortest route</td>
<td></td>
</tr>
</tbody>
</table>

The experiments showed that ACO algorithm gave the most optimal performance when the number of ants was equal to the number of fibre optic panels. Therefore, the shortest route obtained as 366100 km while the number of ants was selected as 56. Table 4 illustrates the optimum route distance and the shortest route for ACO.

As for GA when applying the same number of iterations 3000, it was seen that the results was better than ACO algorithm and the shortest route was obtained as 353400 km. From this results it concluded that the optimum solution for CONR problem is using the GA algorithm with value out of 353400 km. Furthermore, the shortest route obtained with GA was directly drew using actual locations of panels and this route is shown in Fig. 5 which has been taken by the fibre optical cables in Kirkuk city.

![Fig. 5. Shortest Route for Fibre Optics Cables in Kirkuk City](image)

### IV. CONCLUSION

Many techniques have been invented for distribution because of its great role in economic life. In this study, connection oriented network routing was applied in order to provide internet and telephone lines for Kirkuk city and the near regions in Iraqi using optic fiber systems. It was aimed to wire all the panels by fiber optic cables in minimum cost, to raise the data transfer speed, to decrease the excavation process. As a result, two different meta-heuristic algorithms (ACO and GA) were applied to achieve these targets and compared the results of them. After the experiments, the optimum distance between the panels were obtained with ACO and GA as 366100 km and 353400 km, respectively. The results show that GA is the best optimization algorithm for this problem.
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Parallelization of a Hierarchical Graph-Based Image Segmentation using OpenMP

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Abstract—In many image-processing applications, image segmentation is an essential stage. In this stage, an image is partitioned into several regions according to the similarity of its pixels. In addition to the accuracy of the image segmentation, the speed is also very important for real-time image processing applications. Many computer applications take advantages of the multi-processor architecture to up to their running performance. However, to run an algorithm as parallel is very difficult in many cases. Due to using the same memory blocks, many conflicts might be happened between the processors. Moreover, each process of one processor may depend on those of another processor. For this reason, the algorithm to be parallelized must be suitable to parallel. In addition, the processing traffic that is pursued by the processors must be controlled within some parallel directives. In this paper, we provide a parallel implementation to a hierarchical graph-based image segmentation method by using its hierarchical processing steps. To achieve this goal, we utilize the OpenMP (Open Multi-Processing) Library to run the segmentation process as parallel on images of different sizes from the INRIA Holidays dataset. The experimental results show that the parallel implementation of the algorithm is more effective than the serial type according to processing time.

Keywords—Parallel programming; Image segmentation; Graph; OpenMP

I. INTRODUCTION

For many image processing application, the image segmentation is one of the low-level and mid-level image processing stages. During the image segmentation stage, the pixels of an image are grouped into regions according to the similarity in the regions and differences among the regions. This stage is one of the most difficult stages in the image processing applications [1]. The consequence of this stage affects all of the following stages and their results. Image segmentation reduces the large amounts of data for the analysis operations. In an image, the segmentation process inherently focuses on the homogeneous regions and the borders between them. It performs this task by using brightness, color, pattern (texture), or density differences, etc. [2], [3].

Many pattern recognition and computer vision applications take advantage of the global features of the images for more accurate segmentation. However, in this way, the processing time exceeds the allocated time for the input frame periods of the used camera in many real-time computer visions system. Due to the computational complexity of the methods that take into account the global features of the images, those that consider local features are mostly preferred in real-time applications [2].

Graph-based methods are some of the segmentation methods. Because of their representation relevance and ease of retention of images, the graph theory tools are utilized as prominent tools in computer vision [2]. In graph-based segmentation methods, the nodes (or vertices) of the graph refer the pixels of the image and the edges define the connections between the adjacent (or neighboring) vertices. Each of these edges generally has a numerical value, which is called weight [4]. The weights of the edges are considered the difference of the gray level values or color values (if the segmentation is performed on a color image) of the vertices that exists at the ends of the edge. The difference is generally computed by using Euclidean distance measurement [5].

Spanning trees are sub-graphs of a graph; such that they do not contain any loop and it is easy to make process on the graph via the spanning tree structure. The spanning tree of a graph that has the least total edge weight among the other spanning trees of the graph is called minimum spanning tree (MST) [4]. Image segmentation algorithms based on minimum spanning tree take advantage of the features of the MST, because it takes no account of most of the edges on the image-graph. Therefore, the cost of the operation is reduced significantly [6].

The segmentation process in MST-based segmentation algorithms comes true in two ways. The first way is the cutting procedure in which the edges to be cut are removed on the MST that covers all of the pixels of the image. The edges to be cut represent the borders on the image. By this way, a tree is separated into several sub-trees. The sub-trees represent regions in the image [5], [7], [8], [9]. The second way is the merging procedure in which the sub-trees that satisfies a homogeneity criterion are merged [10]. If two sub-trees do not satisfy the criterion, they are not merged, and in this case, the border between the two regions that the two sub-trees represent occurs. In this paper, we parallelize the merging procedure that is performed hierarchically.

Efficient Graph-Based Image Segmentation algorithm, which is proposed by Felzenszwalb and Huttenlocher, defines a merging criterion [10]. The algorithm employs the Kruskal’s algorithm [12], which is one of the most popular MST algorithms. In this algorithm, all of the edges of
the graph structured an image is sorted in ascending order according to their weight. Then, the edges are added to the MST structure by starting the shortest edge, such that the MST is empty at first. If the trees that are at the ends of the edge to be added do not satisfy the merging criterion, the edge is not added. By the way, the MST may be divided into more than one sub-trees. Haxhimusa and Kropatsch [13] used this merging criterion on Boruvka’s hierarchical MST algorithm [14]. In this algorithm, each node (vertex) assumed a sub-tree, and each merging process of these sub-trees actualizes independently from others. For this reason, this makes it suitable for parallelization.

Nowadays, the multi-core processors are prevalent; and therefore, the parallel programming has been a very popular issue. Scientific and engineering programs such as image-processing applications need to be fast to overcome the heavy processing load in limited times. In order to make use of this technology, parallelization of the applications reduces the process load. Obtaining the same or similar results with sequential execution and ensuring to not overlapping of the parallel operations is mostly important and difficult matters for parallel programming issue. In this paper, we organize the hierarchical graph-based image segmentation algorithm as appropriate for parallel execution [15].

II. The Hierarchical Graph-Based Image Segmentation

Let the graph \( G = (V, E) \) be the image-graph that is constructed from an image. \( V \) represents the set of the vertices in the graph \( G \), such that each vertex refers a pixel in the image and \( V \) contains all of the pixel-vertices. \( E \) represents the set of the edges that connects each vertex to its neighboring vertices. In this paper, 8-connected neighborhood is used as a neighborhood system. The edges are generally weighted and undirected. The weight of each edge is a numerical and positive value that indicates the degree of similarity between two vertices at the ends of the edge. As the degree of similarity two vertices is lower, the weight value is higher (Ters orantllar hocam). To figure out the similarity, the one-dimensional gray-scale values or multi-dimensional color values of the pixels can be used, and to compute the difference for both ways, the Euclidean distance measurement can be used. The edge \((u, v)\) connects the vertices \(u\) and \(v\), and \(w(u, v)\) is the Euclidean value of the edge. Let \(x_u\) be the one-level gray-scale value, and \(x_{u,i}\) be the \(i\)-th value of the \(z\)-level color vector of the vertex \(u\) where \(i = \{1, 2, \ldots, z\}\). The Euclidean distance as the weight value of \((u, v)\) is computed as in Eq. 1.

\[
w(u, v) = \sqrt{\sum_{i=1}^{z} (x_{u,i} - x_{v,i})^2} \frac{1}{z}
\]  

A. Boruvka’s Minimum Spanning Tree Algorithm

Boruvka’s MST algorithm constructs an MST structure from a graph, such that the graph must be a weighted, undirected, and complete graph (Fig. 1). According to the algorithm, each vertex is assumed as a tree at first stage and no one is connected to any other one. The union of multiple trees is called forest. At first, all of the vertices compose the forest \(F_0\), because each vertex is a tree such that \(F_0 = T_1 \cup T_2 \cup \ldots \cup T_n\), such that \(n\) refers to the number of the vertices on the graph \(G\). \(T_i\) refers to the \(i\)-th tree \((T_i\) equals to the \(i\)-th vertex at first stage\) and each tree \(T_i\) chooses the smallest edge \((u, v)\) where \(u \in T_i\) and \(v \notin T_i\), then the edge is added to the new forest \(F_1\) that is being composed for the next stage. At the begin of the next stage, the number of the trees will have been reduced by at least one-half, i.e., \(t\) will have been decreased by at least one-half. If any edge is not added in the current stage, on the other words, the last forest \(F_{last}\) has one tree, the algorithm ends.

B. The Graph-Based Segmentation Algorithm

In the MST of a graph representation of an image, the highest weighted edges represent the boundaries of the image (Fig. 1). Felzenszwalb and Huttenlocher have segmented the images by detecting the edges of the boundaries, which are called boundary edges [10], [11]. For the purpose of to detect the boundary edges to be excluded from the

Fig. 1. (a) A simple black and white image , (b) the graph representation of the image according to 4-connection neighborhood, (c) the MST of the image extracted from its graph representation and an example of boundary edge in the MST
MST, Felzenszwalb and Huttenlocher have used the merging criterion Eq. 2 in the Kruskal’s MST algorithm. According to the Kruskal’s algorithm, each vertex in the graph $G$ that is representation of the image seems as a tree. Firstly, all of the edges in $G$ are sorted in order to their weight in ascending order. The two trees at the ends of the smallest weight edge in the sorted edge queue are merged if the two trees are not the same tree, and the edge is removed from the queue. At last, only one single tree remains such that it is called MST [12]. If the merging criterion in Eq. 2 is applied on the algorithm, more than one MSTs might remain at the end of this process [10], because the edges that does not satisfy the criterion are not added to the MST to be formed, and thus, the MST that covers all of the vertices might not be created.

$$\text{Diff}(T_1, T_2) < \min(\text{Int}(T_1) + k/|T_1|, \text{Int}(T_2) + k/|T_2|)$$

(2)

In Eq. 2, $T_1$ and $T_2$ are the sub-trees to be merged. $\text{Diff}(T_1, T_2)$ defines the weight value of the shortest weighted edge that connects the trees $T_1$ and $T_2$. $\text{Int}(T_1)$ and $\text{Int}(T_2)$ defines the internal difference of $T_1$ and $T_2$ respectively. An internal difference of a tree is the weight value of the highest weighted edge in the tree. $|T_1|$ and $|T_2|$ defines the number of vertices in the trees $T_1$ and $T_2$ respectively. The constant value $k$ refers to a threshold value that controls how much greater $\text{Diff}(T_1, T_2)$ must be than the internal differences of the trees $T_1$ and $T_2$.

In this paper, Eq. 2 is utilized as a merging criterion in the Boruvka’s algorithm, because the Boruvka’s algorithm progresses in a hierarchical order. Due to this reason, this algorithm is more suitable for parallelization than the other popular MST algorithms [16]. The hierarchical graph-based image segmentation algorithm is sketched in Fig. 2.

In Fig. 2, the constructed graph $G = (V, E)$ is obtained from the image used, and then it is taken to the process as an input data. Firstly, each vertex seems as a tree. The number of trees $t$ is equal to the number of vertices $|V|$ initially. For each tree $T_i$, the smallest edge $(u, v)$, where $u \in T_i$ and $v \notin T_i$, is found. If the weight value $w(u, v)$ satisfies the criterion in Eq. 2, the tree $T_u$ to which the vertex $u$ belongs and the tree $T_v$ to which the vertex $v$ belongs are merged, and thus, the number of tree is reduced to one. After these processes are complete for each tree, this cycle is repeated iteratively. If no merging is happened, the algorithm ends.

### III. The Parallel Implementation of The Algorithm

#### A. OpenMP

Multi-core processors have become quite prevalent nowadays. Scientific and engineering programs such as image-processing applications need to be fast to overcome the high processing load in limited times. In order to make use of the multi-core processor technology, such applications need to be parallelized. Therefore, some libraries and tools, which are developed to take advantage of the multi-core processor architecture, should be used and the programs that will be parallelized must be coded suitable for parallelization. OpenMP (Open Multi-Processing) is a run-time program library that has routines and environment variables and includes a set of compiler directives. The directives can be embedded into C/C++ and Fortran programming languages using shared-memory platforms to run codes on more processors [17]. On the platforms like these, OpenMP provides an easier programming model. However, getting high performance from OpenMP sometimes might be a very difficult task. The acceleration rate of the program that use OpenMP directives depends on many factors, including the problem how the variables are used in the code, data layout, workload balancing and so on. OpenMP is especially useful for partitioning a loop and running the iterations of the loop on more processors simultaneously. For that, the loop dependencies need to be configured in accordance to parallelism [17].

#### B. Implementation of The Parallel Directives

The parallel computation is put into practice in three ways: general-purpose computing on graphics processing units, via a message processing interface, or using shared memory architecture (OpenMP) [18]. In a shared memory model system, threads, which are processes such that each runs as parallel, are communicated each other by reading and writing directly to the same memory. Since the OpenMP specification was introduced as a standard shared-memory programming model in 1998, there have been many studies to

![Fig. 2. The steps of the hierarchical segmentation algorithm](image)

![Fig. 3. A simple presentation of a shared memory architecture](image)
implement the OpenMP directives to their programs to run as parallel [19]. By using the OpenMP instructions, it is easy to solve the high processing load problems of the classic single pipeline program model, because OpenMP execute some calibrations automatically, and we do not need to consider which core should run in which part of the calculation [20].

OpenMP uses a fork-join model, which is a standard way to execute a parallel program on shared-memory systems (Fig. 3). Firstly, a parallel program begins to run on a single thread called master thread. Once the process flow encounters a parallel block, the process flow is separated to several threads (known as the fork) to run on additional processor cores [21].

OpenMP provides several mechanisms to run the code as parallel. Additionally, OpenMP provides an extra translator that analyzes the parallel loop and generate executor code before the OpenMP translation [19]. The translator determines the number of cores to run, separates the loop into sub-loops automatically according to the number of the cores, and employs each sub-loops to different threats. The example of its use is as below:

```
#pragma omp parallel for
for (i = 0; i < 1000; i++)
{
    x[i] = y[i];
}
```

OpenMP provides some directives as private and shared to define how the parallel regions use the data values. In parallel programming, synchronization is used to impose some order constraints and to organize to access to shared data. OpenMP also provides several mechanisms to synchronize the parallel threads, with critical, atomic, lock, ordered, flush, and barrier [15], [22].

To synchronize the parallel graph-based algorithm, we used the lock directive. In the block for merging clusters, if we embed the locking mechanism in the processes, the threads that each works on a different cluster will also wait to each other [23]. In this way, the flow would not be parallel. Therefore, we restricted to the threads that own the same index of lock array so that the index is the cluster number at the same time. The example of its use is as below:

```
mylock = new omp_lock_t();
omp_init_lock(&mylock);

lock_array = new omp_lock_t[size];
for (i = 0; i < size; i++)
{
    omp_init_lock(&lock_array[i]);
}
```

If a lock is set with the expression omp_set_lock by a processor, other processors that wants to set this lock must be waiting the processor until the lock is unset with the expression omp_unset_lock by the processor that has set the lock.

Another problem for synchronizing the processes is the mutual exclusion problem. In cases when two clusters chose each other as nearest cluster on different threads simultaneously, a crash may happen. To solve this problem, we get the related code into a critical block by the directive critical. By this way, only one processor employs the codes that are in the critical block as seen below:

```
#pragma omp critical
{
    omp_set_lock(&mylock1);
    omp_set_lock(&mylock2);
}
```

There is also another directive for getting the code into a critical block, which is called atomic such that it is used for only one variable to perform faster processing [17]. For example:

```
#pragma omp atomic
    a = a - 1;
```

The input is: Given image graph $G = (V, E)$
The output is: Tree set $T = T_1, T_2, ..., T_t$

```
lock_array = new omp_lock_t[V];
for (i = 1 to V) do
    $T_i \leftarrow v_i$
    omp_init_lock(&lock_array[i])
end for
counter $\leftarrow V$
repeat
    $t \leftarrow counter$
    #pragma omp parallel for private(i) shared(counter)
    for (i = 1 to do)
        $(u, v) \leftarrow T_i$.smallest_adjoring_edge
        #pragma omp critical
        {
            omp_set_lock(&lock_array[T(u).id]);
            omp_set_lock(&lock_array[T(v).id]);
        }
        if $w(u, v) \geq \min (Int(T(u)) + \frac{k}{|T(u)|}, Int(T(v)) + \frac{k}{|T(v)|})$
            omp_unset_lock(&lock_array[T(u).id]);
            omp_unset_lock(&lock_array[T(v).id]);
        continue
    end if
merge $T_u$ and $T_v$
#pragma omp atomic
    counter $\leftarrow counter - 1$
    omp_unset_lock(&lock_array[T(u).id]);
    omp_unset_lock(&lock_array[T(v).id]);
end for
until counter $= t$
```

Fig. 4. Parallel implementation of the algorithm in Fig. 2
The parallel implemented version of the algorithm in Fig. 2 is sketched in Fig. 4.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The system that has been used for the values in Table I has 32 bit Intel i5-2400 3.10-GHz Quad Core processor with 4 GB RAM. We used C++ programming language. To import and illustrate the images, we used OpenCV (Open Source Computer Vision) library [24].

In Fig. 5, the original versions of some images from INRIA Holidays dataset [25], their segmentation results and which processor has performed on which segments of the images in last iteration are presented.

We applied the algorithm on some images from INRIA Holidays dataset [25] in the different versions of the images as the sizes of $128 \times 96$, $256 \times 192$, $512 \times 384$, and $1024 \times 768$. We executed the program five times for each elapsed time

Fig. 5. Visualization of the segmentation results and the task sharing of the processors for some images
value in Table I, and put the smallest one of the five values to the table. The time unit is given as seconds (s) in Table I.

V. CONCLUSIONS

As seen in the results, parallel programming provides an important acceleration in processing speed. However, the processing time decreases no more in all cases, as the number of cores increases. The speedup of the execution relies on many factors, including compiler optimizations, runtime support, data layout, operating system noise, workload balancing and so on. Additionally, it may be dependent on the regions to merge in the structure of the graph of the image. In a parallel loop, even if the threads complete their process except one, they will have to wait for it. In these cases, the operating system might have executed another task on the thread in the meantime. Nevertheless, the parallelization saved a noticeable time for us.

REFERENCES

A Performance Comparison of Graph Coloring Algorithms

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Abstract— Graph coloring problem (GCP) is getting more popular to solve the problem of coloring the adjacent regions in a map with minimum different number of colors. It is used to solve a variety of real-world problems like map coloring, scheduling, graph coloring is associated with two types of coloring as vertex and edge coloring. The goal of the both types of coloring is to color the whole graph without conflicts. Therefore, adjacent vertices or adjacent edges must be colored with different colors. The number of the least possible colors to be used for GCP is called chromatic number. As the number of vertices or edges in a graph increases, the complexity of the problem also increases. Because of this, each algorithm can not find the chromatic number of the problems and may also be different in their executing times. Due to these constructions, GCP is known an NP-hard problem. Various heuristic and metaheuristic methods have been developed in order to solve the GCP. In this study, we described First Fit (FF), Largest Degree Ordering (LDO), Welsh and Powell (WP), Incidence Degree Ordering (IDO), Degrees of Saturation (DSATUR) and Recursive Largest First (RLF) algorithms which have been proposed in the literature for the vertex coloring problem and these algorithms were tested on benchmark graphs provided by DIMACS. The performances of the algorithms were compared as their solution qualities and executing times. Experimental results show that while RLF and DSATUR algorithms are sufficient for the GCP, FF algorithm is generally deficient. WP algorithm finds out the best solution in the shortest time on Register Allocation, CAR, Mycielski, Stanford Miles, Book and Game graphs. On the other hand, RLF algorithm is quite better than the other algorithms on Leighton, Flat, Random (DSJC) and Stanford Queen graphs.

Keywords — Chromatic number, Graph coloring algorithms.

I. INTRODUCTION

Graph theory is a problem represented with vertices (nodes) and edges (arcs) [1]. Otherwise, graph coloring problem (GCP) is a problem where adjacent vertices or edges in graph must be colored by using different colors [2]. GCP was proposed by Francis Gutrie as the four color problem. Four color problem has described by F. Gutrie to solve the problem of coloring the adjacent regions in a map using the minimum number of different colors [3].

Graph coloring is associated with two types of coloring as vertex and edge coloring [2]. The goal of the both types of coloring is to color the whole graph without conflicts. Therefore, adjacent vertices or edges must be colored with different colors. If there is at least one link (edge) between two nodes, it is called adjacent vertices. If the Fig. 1 examines, it can be seen that there is no edge between $V_2$ and $V_4$ vertices. Therefore, these vertices are not adjacent vertices. However, the other vertices in the graph are adjacent because there is at least one edge between each other. In the context of this study we described vertex coloring problem in graphs. If an undirected $G = (V, E)$ graph is examining; $V$ is the set of vertices and $E$ is the set of edges. The graph which is given in Fig. 1, the set of vertices are $V = \{v_1, v_2, v_3, v_4\}$ and the set of edges are $E = \{e_1, e_2, e_3, e_4, e_5\}$. In addition, $R = \{1, 2, \ldots, k\}$ is the set of colors which are used for coloring the vertices. In this case, if the whole graph colored without conflicts is performed by utilizing the minimum number of different colors, it’s called “k-coloring graph” [4]. This minimum number of different colors is known as chromatic number. Chromatic number is indicated by $\chi(G)$ [5,6].

Graph coloring problem is mostly used for solving computer based applications and problems. Graph coloring algorithms are usable for solving the many engineering applications and real-world problems [2]. Some of the these problems are Map Coloring [7], Timetabling and Scheduling problems [8,9], Register Allocation problems [10,11], Sudoku problem [12] and Frequency Assignment problems [13].

As the number of vertices or edges in a graph increases, the complexity of the problem also increases. Because of this, each algorithm can not find the chromatic number of the problems and may also be different in their executing times. Due to these conditions, GCP is known an NP-hard problem [14]. Hence, for getting a better solution for GCP many heuristic and meta-heuristic algorithms are developed. Heuristic algorithms generally can be used for a problem with fewer numbers of vertices. On the other hand, for the complex graphs meta-heuristic algorithms can find better solutions [15].

Tabu Search (TS) Algorithm [16], Simulated Annealing (SA) Algorithm [17], Genetic Algorithm (GA) [7], Ant Colony (ACO) Algorithm [18], Cuckoo (COA) Algorithm [15] are some of the meta-heuristic algorithms used for graph coloring problem. When the vertices in a graph $G$ are colored by means of the greedy algorithms, the coloring issue is
performed with selecting and coloring methods of algorithms. These algorithms are called greedy algorithms because of the algorithms choice the best valid selection for every operation step. The greedy algorithms generally provide effective and sufficient results for vertex coloring [15]. In this study, we described First Fit (FF) [19], Largest Degree Ordering (LDO) [19], Welsh and Powell (WP) [5], Incidence Degree Ordering (IDO) [19], Recursive Largest First (RLF) [20] and Degrees of Saturation (DSATUR) [21] algorithms which have been proposed in the literature for the vertex coloring problem and these algorithms were tested on benchmark graphs provided by DIMACS [22]. The performances of the algorithms were compared with each other in terms of their solution qualities and executing times.

II. VERTEX COLORING PROBLEM

If the vertices in a graph are colored with different colors without considering their adjacencies, this graph would be colored utilizing the number of the different colors which are equal to number of vertices. However, this is not a good solution for GCP. Because, the purpose of the GCP is to find the minimum number of the colors for adjacent vertices colored with different colors.

As the number of vertices or edges in a graph increases, the complexity of the graph also increases. Because of this, coloring the entire graph is getting difficult by the least possible different colors. Therefore, we need some particular methods for coloring the graphs. Thanks to particular methods, the graphs can be colored with minimal different colors.

Algorithms in the literature use the adjacency matrix for coloring the vertices of graphs. Adjacency matrix is generated based on the condition that whether any edge exists between vertices [1]. For a graph, the set of vertices are shown in the set of \( V = \{v_1, v_2, \ldots, v_n\} \). The adjacency matrix of a graph is generated by the equation. \( A \) is represents the adjacency matrix.

\[
A = \begin{cases} 
1, & \text{if there is an edge between } v_i \text{ and } v_j \\
0, & \text{otherwise} 
\end{cases} \quad (1)
\]

Another important constraint for the selection of the vertex to be colored is vertex degrees. A degree of a vertex in an undirected and unweight graph is equal to the total number of edges connected to the vertex. It’s shown with \( deg(v_i) \) [1]. The graph given in Fig. 2 has seven vertices and nine edges.

![Figure 2. A graph with seven vertices](image)

Table I shows the adjacency matrix for the graph presented in Fig. 2 and and Table II shows the degrees of vertices for this graph.

III. VERTEX COLORING ALGORITHMS IN GRAPHS

At this section of the study we describe the steps of the some algorithms which have been proposed in the literature for the vertex coloring problem. Also these algorithms will be tested on the graph in Fig. 2. Then the selecting order of the vertices and the color of each vertex are given.

A. First Fit Algorithm (FF)

For the given graph, the set of the vertices is described as \( V = \{v_1, v_2, \ldots, v_n\} \) and the set of the colors is described as \( R = \{r_1, r_2, \ldots, r_k\} \). The steps of the algorithm:

**Step 1**: Create a color set. (initially the color set is empty).

**Step 2**: The first vertex in the set of \( V \) is selected as the starting vertex. The selected vertex is colored with first color and this color is added to color set.

**Step 3**: Next vertex in the set of \( V \) is selected for coloring.

**Step 4**: For selected vertex, find the adjacent vertices of it from the adjacency matrix. A color which is in the color set, but not color of the adjacent vertices of selected vertex is given to the selected vertex. If the colors in the color set unsuitable for coloring the selected vertex, a new color is defined. The new color is added to the color set and appointed to the selected vertex. If the uncolored vertex exists, it is returned to the next.

Table III shows the result for the graph shown in Fig. 2. Selected order of the vertices and their colors are given in Table III. According to Table III, the first colored vertex is \( A \) and the color \( r_1 \) is given this vertex. The last colored vertex is \( G \) and the color \( r_3 \) is given this vertex.

![Table I: Adjacency Matrix](image)

![Table II: The Degrees of Vertices](image)

![Table III: The Result of the Colored Graph Using the FF Algorithm](image)
B. Welsh Powell Algorithm (WP)

For the given graph $G$, the set of the vertices is described as $V = \{v_1, v_2, \ldots, v_n\}$ and the set of the colors of the vertices is described as $R = \{r_1, r_2, \ldots, r_k\}$ . The steps of the WP algorithm:

**Step 1**: The vertex degree of each vertex is calculated and the vertex degrees are added to the degree set $\text{Deg}(v_i)$, such that $i = 1,2, \ldots, n$.

**Step 2**: The uncolored vertex that has the largest degree in the degree set $\text{Deg}(v_i)$ is selected for coloring. Initially, the first color in the color set is selected as the active color.

**Step 3**: The selected vertex is colored with active color. After that, find the uncolored vertices from adjacency matrix which are not adjacent vertices of the colored vertex and these vertices are added to the $V'$ set ( $V' = \{v'_1, v'_2, \ldots, v'_n\}$).

- The uncolored vertex that has the largest degree in the $V'$ is selected for coloring. This vertex is colored with active color. After that, the adjacent vertices of this vertex are deleted from $V'$. This step is repeated until all vertices colored in the set of $V'$.

**Step 4**: If the uncolored vertex exists, next color in the color set is selected as active color and it is returned to the step 2. Otherwise the program is terminated, because all vertices in the graph are colored.

Table IV shows the result for the graph shown in Fig. 2. Selected order of the vertices and their colors are given in Table IV.

<table>
<thead>
<tr>
<th>Selected order</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex color</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

C. Largest Degree Ordering Algorithm (LDO)

For the given graph $G$, the set of the vertices is described as $V = \{v_1, v_2, \ldots, v_n\}$ and the set of the colors of the vertices is described as $R = \{r_1, r_2, \ldots, r_k\}$ . The steps of the LDO algorithm:

**Step 1**: Create a color set. (initially the color set is empty). The vertex degree of each vertex is calculated and the vertex degrees are added to the degree set $\text{Deg}(v_i)$, such that $i = 1,2, \ldots, n$.

**Step 2**: The uncolored vertex that has the largest degree in the degree set $\text{Deg}(v_i)$ is selected for coloring. Firstly, the selected vertex is tried to color with the colors in the color set. If the color set is empty or the colors in the color set are not appropriate (all colors int the color set used from the adjacent vertices) for color the vertex, a new color is defined. The new color is added to the color set and appointed to the selected vertex.

**Step 3**: If the uncolored vertex exists, it is returned to the step 2. Otherwise the program is terminated.

Table V shows the result for the graph shown in Fig. 2. Selected order of the vertices and their colors are given in Table V.

<table>
<thead>
<tr>
<th>Selected order</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex color</td>
<td>r_3</td>
<td>r_2</td>
<td>r_1</td>
<td>r_2</td>
<td>r_1</td>
<td>r_1</td>
<td></td>
</tr>
</tbody>
</table>

D. Incidence Degree Ordering Algorithm (IDO)

For the given graph $G$, the set of the vertices is described as $V = \{v_1, v_2, \ldots, v_n\}$ and the set of the colors of the vertices is described as $R = \{r_1, r_2, \ldots, r_k\}$ . The steps of the IDO algorithm:

**Step 1**: The vertex degree of each vertex is calculated and the vertex degrees are added to the degree set $\text{Deg}(v_i)$, such that $i = 1,2, \ldots, n$. Initially, there is just one color in the color set.

**Step 2**: The uncolored vertex that has the largest degree in the degree set $\text{Deg}(v_i)$ is selected for coloring. The selected vertex is colored with the first color.

**Step 3**: The number of the colored adjacent vertices is calculated for every uncolored vertices. After that, the uncolored vertex whose colored neighboring vertices are the maximum is selected. If more than one vertex provides this condition, the vertex which has the largest degree among them is selected.

**Step 4**: Firstly, the selected vertex with the colors in the color set is tried to color. If the colors in the color set are not appropriate to color the vertex, a new color is defined. The new color is added to the color set and appointed to the selected vertex.

**Step 5**: If the uncolored vertex exists, it is returned to the step 3. Otherwise, the program is terminated.

Table VI shows the result for the graph shown in Fig. 2. Selected order of the vertices and their colors are given in Table VI.

<table>
<thead>
<tr>
<th>Selected order</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex color</td>
<td>r_3</td>
<td>r_2</td>
<td>r_1</td>
<td>r_2</td>
<td>r_1</td>
<td>r_1</td>
<td></td>
</tr>
</tbody>
</table>

E. Degrees of Saturation Algorithms (DSATUR)

For the given graph $G$, the set of the vertices is described as $V = \{v_1, v_2, \ldots, v_n\}$ and the set of the colors of the vertices is described as $R = \{r_1, r_2, \ldots, r_k\}$ . The steps of the DSATUR algorithm:

**Step 1**: The vertex degree of each vertex is calculated and the vertex degrees are added to the degree set $\text{Deg}(v_i)$, such that $i = 1,2, \ldots, n$. 

**Step 2:** The uncolored vertex that has the largest degree in the degree set $\text{Deg}(v_i)$ is selected for coloring. The selected vertex is colored with first color.

**Step 3:** Firstly, calculate the number adjacent vertices which are colored with different colors for every uncolored vertex. After that, the uncolored vertex whose number of adjacent vertices colored with different colors is the maximum is selected for coloring. If more than one vertex provide this condition, the vertex which has the largest degree among them is selected.

**Step 4:** Firstly, the selected vertex is tried to color with active color. If the uncolored vertex exists, next color in the color set is selected as active color. Otherwise the program is terminated.

**Step 5:** If the uncolored vertex exists, it is returned to the step 3. Otherwise the program is terminated.

For DSATUR algorithm, Table VII shows the result for the graph shown in Fig. 2.

**Table VII**

<table>
<thead>
<tr>
<th>Selected order</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex color</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**F. Recursive Largest First Algorithm (RLF)**

RLF is used a recursive structure for coloring the vertices in graph. This recursive structure is the most important feature of the RLF algorithm [20]. According to this recursive structure, whole graph is colored with minimum different colors. For the given $G$ graph, the set of the vertices is described as $V = \{v_1, v_2, ..., v_n\}$ and the set of the colors is described as $R = \{r_1, r_2, ..., r_k\}$. The steps of the RLF algorithm:

**Step 1:** Vertex degree is calculated for each vertex and the degrees of vertices added to the set of $\text{Deg}(v_i)$. Initially, the first color in the color set is selected as the active color. Select the uncolored vertex which has the largest degree from set of $\text{Deg}(v_i)$ for coloring.

**Step 2:** The selected vertex is colored with active color. Adjacent vertices of the selected vertex can not color with active color. But the uncolored vertices which are not adjacent vertices of the colored vertex can be colored with active color. So RLF uses a recursive structure for select the uncolored vertices to color with active color. During this process the below steps should be followed:

- Adjacent vertices of the selected vertex $v_i$ are found from adjacency matrix. Adjacent vertices are added to the adjacent set $U$. ($U = \{u_1, u_2, ..., u_k\}$
- The vertices which are not adjacent vertices of the selected vertex $v_i$ are found from adjacency matrix. These vertices are added to the set of $V'$. Calculate the number adjacent vertices which are in the set of $U$ for every vertex in set of $V'$. After that, the uncolored vertex whose has maximum adjacent vertices (which are in the set of $U$) in the set of $V'$ is selected for coloring. The selected vertex is colored with active color.
- The colored vertex and the adjacent vertices of the colored vertex are deleted from $V'$ and added to the set of $U$.
- If the set of $V'$ is not empty, it is returned to the step 2. Otherwise move to step 3.

**Step 3:** If the uncolored vertex exists, next color in the color set is selected as active color. Otherwise the program is terminated.

**Step 4:** Calculate the number adjacent vertices for every uncolored vertex. After that, the uncolored vertex whose has maximum adjacent vertices is selected for coloring process. If more than one vertex provide this condition, the vertex which has the largest degree among them is selected. Then, it is returned to the step 2.

For RLF algorithm, Table VIII shows the result for the graph shown in Fig. 2. Selected order of the vertices and their colors are given in Table VIII.

**Table VIII**

<table>
<thead>
<tr>
<th>Selected order</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertex color</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**IV. Experiment Result**

FF, LDO, WP, IDO, DSATUR and RLF algorithms were tested on benchmark graphs provided by DIMACS [22]. The reason of preferring the DIMACS graph, it’s given a standard for performance comparison of the algorithms. The performances of the algorithms were compared as their solution quality and executing times. The edge density ($D$) of the benchmark graphs which are used in this study are calculated from equation 2. $E$ represents the number of the edges and $V$ represents the vertices number of the graph [23].

$$D = \frac{2 * E}{V * (V - 1)} \quad (2)$$

In this study we used Mycielski, CAR, Stanford Graph Base (SGB), Register Allocation, Leighton, Flat, Random (DSJC) and Random geometric (DSJR and R250) DIMACS graphs. $V$ represents the number of the vertices, $E$ is the number of the edges, $Den.$ represents density, $\text{Best}/\chi(G)$ means chromatic number or the best known number, $R$ represents the number of colors that algorithms are found, $T$ is computation time in seconds. The algorithms are written in the programming language Matlab R2010a. For experiments we used a Laptop.
Mycielski graphs are triangle free graphs. It’s mean that the edge connections in the graph must be free of triangle. For mycielski graph, if the vertices in the graph increases, the number of the colors for coloring the graph increases too [24]. Stanford GraphBase (SGB) graphs are created from Donald Knuth. SGB graph can be divided to books, miles, game and queen graphs [22]. For books graphs, a character in the book represents a vertex. So the books graphs are created for holds to relationship between characters. If the characters in the book have relationship to each other, an edge is generated between two vertex characters run across in the book. These books are Charles Dicken’s David Copperfield (david), Victor Hugo’s Les Misérables (Jean), Lev Tolstoy’s Anna Karenina (Anna), Homer’s Iliad (Homer) and Mark Twain’s Huckleberry Finn (Huck). For miles graphs the vertices represents some of the United States cities and if there is a road between two cities which provides the conditions, there is an edge generated between them. For game graph, any vertex in the graph represents a college team. There is an edge generated between for every two teams when the teams played to each other during the season. Table IX shows the results for algorithms which are used for this study. Except the FF algorithm all other algorithms find out the best χ(G) results. In addition, FF algorithm finds out the best χ(G) results for graphs which are used for this study except miles graphs and anna, David, Homer graph. On the other hand, if the algorithms compared to each other about their computation times, WP algorithm is reached these conclusions in a quite short time.

**TABLE IX**

<table>
<thead>
<tr>
<th>Graph</th>
<th>V</th>
<th>E</th>
<th>Den.</th>
<th>Best/χ(G)</th>
<th>RLF</th>
<th>DSATUR</th>
<th>WP</th>
<th>LDO</th>
<th>IDO</th>
<th>FF</th>
</tr>
</thead>
<tbody>
<tr>
<td>myciel3</td>
<td>11</td>
<td>20</td>
<td>0.33</td>
<td>4</td>
<td>4</td>
<td>0.0004</td>
<td>4</td>
<td>0.0023</td>
<td>4</td>
<td>0.0001</td>
</tr>
<tr>
<td>myciel4</td>
<td>23</td>
<td>1</td>
<td>0.27</td>
<td>6</td>
<td>5</td>
<td>0.0009</td>
<td>5</td>
<td>0.0077</td>
<td>5</td>
<td>0.0025</td>
</tr>
<tr>
<td>myciel5</td>
<td>47</td>
<td>1</td>
<td>0.26</td>
<td>7</td>
<td>6</td>
<td>0.0052</td>
<td>6</td>
<td>0.0255</td>
<td>6</td>
<td>0.0003</td>
</tr>
<tr>
<td>myciel6</td>
<td>95</td>
<td>1</td>
<td>0.17</td>
<td>7</td>
<td>7</td>
<td>0.0075</td>
<td>7</td>
<td>0.0976</td>
<td>7</td>
<td>0.0004</td>
</tr>
<tr>
<td>myciel7</td>
<td>191</td>
<td>1</td>
<td>0.13</td>
<td>8</td>
<td>8</td>
<td>0.0293</td>
<td>8</td>
<td>0.3254</td>
<td>8</td>
<td>0.0006</td>
</tr>
<tr>
<td>miles1000</td>
<td>128</td>
<td>32</td>
<td>0.39</td>
<td>42</td>
<td>42</td>
<td>0.1065</td>
<td>42</td>
<td>1.2942</td>
<td>43</td>
<td>0.016</td>
</tr>
<tr>
<td>miles1500</td>
<td>128</td>
<td>51</td>
<td>0.63</td>
<td>73</td>
<td>73</td>
<td>0.3158</td>
<td>73</td>
<td>2.6877</td>
<td>73</td>
<td>0.024</td>
</tr>
<tr>
<td>miles500</td>
<td>128</td>
<td>11</td>
<td>0.14</td>
<td>20</td>
<td>20</td>
<td>0.0250</td>
<td>20</td>
<td>0.3249</td>
<td>20</td>
<td>0.0010</td>
</tr>
<tr>
<td>miles750</td>
<td>213</td>
<td>0.26</td>
<td>31</td>
<td>31</td>
<td>31</td>
<td>0.0522</td>
<td>31</td>
<td>0.7112</td>
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<td>0.0003</td>
</tr>
<tr>
<td>anna</td>
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<td>11</td>
<td>11</td>
<td>11</td>
<td>0.0135</td>
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<td>0.1231</td>
<td>11</td>
<td>0.0001</td>
</tr>
<tr>
<td>david</td>
<td>87</td>
<td>0.11</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>0.0076</td>
<td>11</td>
<td>0.1026</td>
<td>11</td>
<td>0.0065</td>
</tr>
<tr>
<td>hommer</td>
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<td>0.01</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>0.3404</td>
<td>13</td>
<td>0.5413</td>
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<td>0.0024</td>
</tr>
<tr>
<td>buck</td>
<td>74</td>
<td>0.11</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>0.0062</td>
<td>11</td>
<td>0.0745</td>
<td>11</td>
<td>0.0055</td>
</tr>
<tr>
<td>jean</td>
<td>80</td>
<td>0.08</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>0.0060</td>
<td>10</td>
<td>0.0616</td>
<td>10</td>
<td>0.0004</td>
</tr>
<tr>
<td>games120</td>
<td>120</td>
<td>0.09</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>0.0180</td>
<td>9</td>
<td>0.1537</td>
<td>9</td>
<td>0.0006</td>
</tr>
</tbody>
</table>

R: Result of the algorithm, T: Computation time (in second)

Queen graphs are n x n dimensional chessboard graphs. If two queens on the chessboard are in the same row, column, or diagonal, there is an edge generated between them. So, if two queens placed in same row, column or diagonal, one queen can eat the other one. Because of this, there is an edge between them for they don’t eat each other. For queens graph if only the graph is colored with minimum number n, two queens can move on chessboard. Table X shows the results for queens graphs. Experimental results show that while RLF and DSATUR algorithms are sufficient for the queens graphs, but the other algorithms are generally deficient. RLF algorithm finds out just only the chromatic number of queen5_5 graph and also it finds out quite better results for the other queen graphs. DSATUR algorithm generally finds out good results, but it is very slow according to the RLF.

**TABLE X**

<table>
<thead>
<tr>
<th>Graph</th>
<th>V</th>
<th>E</th>
<th>Den.</th>
<th>Best/χ(G)</th>
<th>RLF</th>
<th>DSATUR</th>
<th>WP</th>
<th>LDO</th>
<th>IDO</th>
<th>FF</th>
</tr>
</thead>
<tbody>
<tr>
<td>queen5_5</td>
<td>25</td>
<td>160</td>
<td>0.51</td>
<td>5</td>
<td>5</td>
<td>0.0012</td>
<td>5</td>
<td>0.0322</td>
<td>5</td>
<td>0.0003</td>
</tr>
<tr>
<td>queen6_6</td>
<td>36</td>
<td>290</td>
<td>0.45</td>
<td>7</td>
<td>8</td>
<td>0.0028</td>
<td>9</td>
<td>0.0634</td>
<td>9</td>
<td>0.0003</td>
</tr>
<tr>
<td>queen7_7</td>
<td>49</td>
<td>476</td>
<td>0.40</td>
<td>7</td>
<td>9</td>
<td>0.0045</td>
<td>11</td>
<td>0.1090</td>
<td>12</td>
<td>0.0005</td>
</tr>
<tr>
<td>queen8_8</td>
<td>96</td>
<td>1368</td>
<td>0.30</td>
<td>12</td>
<td>13</td>
<td>0.0202</td>
<td>14</td>
<td>0.3851</td>
<td>15</td>
<td>0.0007</td>
</tr>
<tr>
<td>queen9_9</td>
<td>64</td>
<td>728</td>
<td>0.36</td>
<td>9</td>
<td>11</td>
<td>0.0081</td>
<td>12</td>
<td>0.1783</td>
<td>13</td>
<td>0.0005</td>
</tr>
<tr>
<td>queen10_10</td>
<td>81</td>
<td>1056</td>
<td>0.32</td>
<td>10</td>
<td>12</td>
<td>0.0154</td>
<td>13</td>
<td>0.2853</td>
<td>15</td>
<td>0.0007</td>
</tr>
</tbody>
</table>
CAR graphs are created from inspiration of the mycielski graphs. After the some new vertices inserted graph, the graph size increases, but the density of the graph is unchanging [25]. The CAR graphs are more difficult than the mycielski graphs. Table XI shows the results for CAR graphs. According to the Table XI; RLF, DSATUR, WP and LDO algorithms reach the best/χ(G) results. Furthermore the IDO algorithm generally finds out the best/χ(G) results. But FF algorithm is generally deficient. If the algorithms compare to each other about their computation times, the best algorithm for CAR graphs is WP algorithm. Because WP algorithm reaches the best/χ(G) results shortest computation times.

### Table XI

<table>
<thead>
<tr>
<th>Graph</th>
<th>V</th>
<th>E</th>
<th>Den.</th>
<th>Best/χ(G)</th>
<th>Computation (in second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fullins_4</td>
<td>93</td>
<td>593</td>
<td>0.14</td>
<td>5</td>
<td>0.0069 0.0869 0.00035 0.00211 0.0298 0.0016</td>
</tr>
<tr>
<td>1. Fullins_5</td>
<td>282</td>
<td>327</td>
<td>0.08</td>
<td>6</td>
<td>0.0612 0.5026 0.00007 0.01047 0.2167 0.0098</td>
</tr>
<tr>
<td>1. Insertions_4</td>
<td>67</td>
<td>232</td>
<td>0.10</td>
<td>5</td>
<td>0.0058 0.0258 0.00002 0.00013 0.00990 0.00088</td>
</tr>
<tr>
<td>1. Insertions_5</td>
<td>202</td>
<td>1227</td>
<td>0.06</td>
<td>6</td>
<td>0.0314 0.1527 0.00005 0.00556 0.05696 0.00388</td>
</tr>
<tr>
<td>1. Insertions_6</td>
<td>607</td>
<td>6337</td>
<td>0.03</td>
<td>7</td>
<td>0.3575 1.2288 0.00023 0.00344 0.60117 0.03088</td>
</tr>
<tr>
<td>2. Fullins_4</td>
<td>52</td>
<td>201</td>
<td>0.15</td>
<td>5</td>
<td>0.0027 0.0237 0.00002 0.00010 0.00760 0.00008</td>
</tr>
<tr>
<td>2. Fullins_5</td>
<td>212</td>
<td>1621</td>
<td>0.07</td>
<td>6</td>
<td>0.0329 0.2116 0.00006 0.00060 0.07964 0.00528</td>
</tr>
<tr>
<td>2. Fullins_6</td>
<td>852</td>
<td>12201</td>
<td>0.03</td>
<td>7</td>
<td>0.8307 3.2494 0.00044 0.00070 1.8256 0.07638</td>
</tr>
<tr>
<td>2. Insertions_4</td>
<td>149</td>
<td>541</td>
<td>0.05</td>
<td>5</td>
<td>0.0188 0.0621 0.00004 0.00036 0.02300 0.00218</td>
</tr>
<tr>
<td>2. Insertions_5</td>
<td>597</td>
<td>3936</td>
<td>0.02</td>
<td>6</td>
<td>0.3721 0.6322 0.00023 0.00026 0.2965 0.02118</td>
</tr>
<tr>
<td>3. Fullins_4</td>
<td>80</td>
<td>346</td>
<td>0.11</td>
<td>6</td>
<td>0.0060 0.0380 0.00003 0.00017 0.01342 0.01212</td>
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<tr>
<td>3. Fullins_5</td>
<td>405</td>
<td>3524</td>
<td>0.04</td>
<td>7</td>
<td>0.1476 0.5534 0.00012 0.00157 0.23700 0.01500</td>
</tr>
<tr>
<td>3. Fullins_6</td>
<td>2030</td>
<td>33751</td>
<td>0.02</td>
<td>8</td>
<td>10.3646 18.3988 0.0254 0.37865 1.15821 0.46000</td>
</tr>
<tr>
<td>3. Insertions_4</td>
<td>56</td>
<td>110</td>
<td>0.07</td>
<td>4</td>
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</tr>
<tr>
<td>3. Insertions_5</td>
<td>281</td>
<td>1046</td>
<td>0.03</td>
<td>5</td>
<td>0.0731 0.1288 0.00007 0.00073 0.0498 0.00488</td>
</tr>
<tr>
<td>3. Insertions_6</td>
<td>1406</td>
<td>9695</td>
<td>0.01</td>
<td>6</td>
<td>3.6966 3.2069 0.01285 0.01101 1.7266 0.09966</td>
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<tr>
<td>4. Fullins_4</td>
<td>114</td>
<td>541</td>
<td>0.08</td>
<td>7</td>
<td>0.0107 0.0610 0.00004 0.00026 0.0216 0.00200</td>
</tr>
<tr>
<td>4. Fullins_5</td>
<td>690</td>
<td>6650</td>
<td>0.03</td>
<td>8</td>
<td>0.5299 1.2976 0.00031 0.00386 0.6677 0.0387</td>
</tr>
<tr>
<td>4. Fullins_6</td>
<td>4146</td>
<td>77305</td>
<td>0.01</td>
<td>9</td>
<td>89.5661 85.9533 0.1131 1.6550 55.6602 2.02899</td>
</tr>
<tr>
<td>4. Insertions_4</td>
<td>79</td>
<td>156</td>
<td>0.05</td>
<td>4</td>
<td>0.0065 0.0180 0.00002 0.00015 0.00684 0.00009</td>
</tr>
<tr>
<td>4. Insertions_5</td>
<td>475</td>
<td>1795</td>
<td>0.02</td>
<td>5</td>
<td>0.2527 0.2467 0.0015 0.0188 0.1009 0.0103</td>
</tr>
<tr>
<td>5. Fullins_4</td>
<td>154</td>
<td>792</td>
<td>0.07</td>
<td>8</td>
<td>0.0228 0.0982 0.00018 0.0036 0.0332 0.00298</td>
</tr>
<tr>
<td>5. Fullins_5</td>
<td>1085</td>
<td>11395</td>
<td>0.02</td>
<td>9</td>
<td>1.8848 2.9627 0.0080 0.00874 1.6530 0.09238</td>
</tr>
</tbody>
</table>

Random (DSJ) graphs which are created from David Johnson and R250_5 graph are difficult to solve benchmark graphs [15]. Flat graphs are created from Culberson. [26]. First parameter of the Flat graphs represents the number of the vertices and the second parameter represents the chromatic number. Table XII shows the results for Random and Flat graphs. According to the Table XII, RLF and DSATUR algorithms generally find out the best/χ(G) results. For the R250_5 graph, DSATUR algorithm’s computation time is further than RLF’s. But DSATUR finds out quite better result than RLF for R250_5 graph. On the other hand, RLF finds out quite better results for the other graphs and RLF is faster than the other algorithms.

### Table XII

<table>
<thead>
<tr>
<th>Graph</th>
<th>V</th>
<th>E</th>
<th>Den.</th>
<th>Enity/ (\chi(G))</th>
<th>Computation (in second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSJC125_1</td>
<td>125</td>
<td>736</td>
<td>0.09</td>
<td>5</td>
<td>0.0135 0.0846 0.00055 0.00320 0.00024</td>
</tr>
<tr>
<td>DSJC125_5</td>
<td>125</td>
<td>3891</td>
<td>0.50</td>
<td>17</td>
<td>0.0468 0.6111 0.0011 0.00709 0.2966 0.00774</td>
</tr>
<tr>
<td>DSJC125_9</td>
<td>125</td>
<td>6961</td>
<td>0.89</td>
<td>44</td>
<td>0.1811 1.4215 0.0019 0.00162 0.7575 0.01554</td>
</tr>
</tbody>
</table>
fpsol2*, inithx*, zeroin* and mulsol* graphs are computer register allocation problem graphs which are generated from Gary Lewandowski [24]. These graphs are real-world problem’s graphs. The computer registers and the operations are defined as vertices. If a register and an operation have a relationship, there is an edge generated between them. Table XIII shows the results for computer register allocation graphs.

In the Leighton graphs, each graph consists of 450 vertices. First parameter of the Leighton graphs represents the number of the vertices and the second parameter represents the chromatic number [20]. Table XIV shows the results for Leighton graphs. Experimental results show that RLF algorithm finds out quite better results for Leighton graphs. Just for le450_25b graph, WP algorithm finds out the $\chi(G)$ result the better computation time. The other algorithms are generally deficient.

### Table XIII

<table>
<thead>
<tr>
<th>Graph</th>
<th>V</th>
<th>E</th>
<th>Den.</th>
<th>Best/$\chi(G)$</th>
<th>RLF R</th>
<th>DSATUR R</th>
<th>WP R</th>
<th>LDO T</th>
<th>IDO T</th>
<th>FF T</th>
</tr>
</thead>
<tbody>
<tr>
<td>fpsol2_t1</td>
<td>496</td>
<td>11654</td>
<td>0.09</td>
<td>65</td>
<td>65</td>
<td>0.9869</td>
<td>31</td>
<td>1791</td>
<td>65</td>
<td>0.0044</td>
</tr>
<tr>
<td>fpsol2_t2</td>
<td>451</td>
<td>8691</td>
<td>0.09</td>
<td>30</td>
<td>30</td>
<td>0.5217</td>
<td>30</td>
<td>19960</td>
<td>30</td>
<td>0.0024</td>
</tr>
<tr>
<td>fpsol2_t3</td>
<td>425</td>
<td>8688</td>
<td>0.10</td>
<td>30</td>
<td>30</td>
<td>0.5184</td>
<td>30</td>
<td>19752</td>
<td>30</td>
<td>0.0022</td>
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<tr>
<td>mulsol_t1</td>
<td>197</td>
<td>3925</td>
<td>0.20</td>
<td>49</td>
<td>49</td>
<td>0.1299</td>
<td>49</td>
<td>6347</td>
<td>49</td>
<td>0.0021</td>
</tr>
<tr>
<td>mulsol_t2</td>
<td>188</td>
<td>3885</td>
<td>0.22</td>
<td>31</td>
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<td>0.1171</td>
<td>31</td>
<td>6423</td>
<td>31</td>
<td>0.0015</td>
</tr>
<tr>
<td>mulsol_t3</td>
<td>184</td>
<td>3916</td>
<td>0.23</td>
<td>31</td>
<td>31</td>
<td>0.1164</td>
<td>31</td>
<td>6189</td>
<td>31</td>
<td>0.0015</td>
</tr>
<tr>
<td>mulsol_t4</td>
<td>185</td>
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<td>31</td>
<td>0.1243</td>
<td>31</td>
<td>6328</td>
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<td>0.0015</td>
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<tr>
<td>mulsol_t5</td>
<td>186</td>
<td>3973</td>
<td>0.23</td>
<td>31</td>
<td>31</td>
<td>0.1253</td>
<td>31</td>
<td>6286</td>
<td>31</td>
<td>0.0015</td>
</tr>
<tr>
<td>inithx_t1</td>
<td>646</td>
<td>18707</td>
<td>0.05</td>
<td>54</td>
<td>54</td>
<td>2.7427</td>
<td>54</td>
<td>6714</td>
<td>54</td>
<td>0.0006</td>
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<tr>
<td>inithx_t2</td>
<td>645</td>
<td>13979</td>
<td>0.07</td>
<td>31</td>
<td>31</td>
<td>1.4014</td>
<td>31</td>
<td>42319</td>
<td>31</td>
<td>0.0037</td>
</tr>
<tr>
<td>inithx_t3</td>
<td>621</td>
<td>13969</td>
<td>0.07</td>
<td>31</td>
<td>31</td>
<td>1.3034</td>
<td>31</td>
<td>41724</td>
<td>31</td>
<td>0.0035</td>
</tr>
<tr>
<td>zeroin_t1</td>
<td>211</td>
<td>4100</td>
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<td>49</td>
<td>0.1427</td>
<td>49</td>
<td>6636</td>
<td>49</td>
<td>0.0020</td>
</tr>
<tr>
<td>zeroin_t2</td>
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<td>3541</td>
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<td>0.1062</td>
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<td>0.5390</td>
<td>30</td>
<td>0.0014</td>
</tr>
<tr>
<td>zeroin_t3</td>
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<td>30</td>
<td>30</td>
<td>0.1150</td>
<td>30</td>
<td>0.5439</td>
<td>30</td>
<td>0.0014</td>
</tr>
</tbody>
</table>

R: Result of the algorithm, T: Computation time (in second)

### Table XIV

<table>
<thead>
<tr>
<th>Graph</th>
<th>V</th>
<th>E</th>
<th>Den.</th>
<th>Eniyl/$\chi(G)$</th>
<th>RLF R</th>
<th>DSATUR R</th>
<th>WP R</th>
<th>LDO T</th>
<th>IDO T</th>
<th>FF T</th>
</tr>
</thead>
<tbody>
<tr>
<td>le450_15b</td>
<td>450</td>
<td>8169</td>
<td>0.08</td>
<td>15</td>
<td>15</td>
<td>0.3071</td>
<td>16</td>
<td>1.7589</td>
<td>18</td>
<td>0.0025</td>
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<tr>
<td>le450_25a</td>
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<td>8260</td>
<td>0.08</td>
<td>25</td>
<td>25</td>
<td>0.3502</td>
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<td>1.7952</td>
<td>26</td>
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<td>0.08</td>
<td>25</td>
<td>25</td>
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<td>1.9924</td>
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<tr>
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<td>5.9978</td>
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<tr>
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<td>0.2226</td>
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</tr>
<tr>
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<td>9757</td>
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<td>0.2315</td>
<td>12</td>
<td>2.4073</td>
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<td>0.0025</td>
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</tbody>
</table>

R: Result of the algorithm, T: Computation time (in second)
V. CONCLUSION

Experimental results show that while RLF and DSATUR algorithms are sufficient for the GCP, FF algorithm is generally deficient. WP algorithm finds out the best solution in the shortest time on Register Allocation, CAR, Mycielski, Stanford Miles, Book and Game graphs. On the other hand, RLF algorithm is quite better than the other algorithms on Leighton, Flat, Random (DSJC) and Stanford Queen graphs. As shown in the study, firstly it should be decided that the problems which we want to solve with graph coloring algorithms is similar to what benchmark graphs. After that, the optimum graph coloring algorithms must be applied to the problem for finds out the the best solution. Thus, it can be avoided to waste of times and it can be reached the best results a quite short time.

REFERENCES

Design of an Interface for Genetic Algorithm Based Optimization of Function

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Abstract—Many analytical solutions for linear and nonlinear mathematical equations and equation systems have been developed and still continue to be developed. However, in some cases, difficulties may be encountered to achieve the results by analytical solutions. Quantitative analysis gained importance and their use has increased in parallel to developments in quantitative electronics especially in computer sciences. In recent years, the use of intuitive/evolutionary algorithms has become very common. In this study, a user-friendly graphical interface programme that works genetic algorithm-based for optimization operations is designed. Optimization of many test functions is performed by genetic algorithms, the results and properties are presented to the user both quantitatively and graphically.

Keywords—Genetic Algorithm, Optimization, Simulator

I. INTRODUCTION

Various analytical methods have been developed and still are being developed for the solution of mathematical equation systems (linear and nonlinear equations). The use of computer-based numerical methods that makes the iteration number fast which will be done many times, makes the solution easier instead of the use of classical methods for the solutions in the mathematical equations in real life. In recent years, computer-based genetically algorithms (GA) are used commonly in areas such as every kind of solution of optimization problems.

Many studies are present relative to solutions of equations with genetic algorithms in the literature. There are some applications such as simultaneous solution of linear systems of equations [1], finding the roots of algebraic equations [2], the solution of linear and nonlinear equations [3], the solution of quadratic equations [4], finding the roots of first, second, third, fourth and fifth degree polinom equations [5], the solution of Poisson equations [6].

In this study, a genetic algorithm-based graphical interface programme aimed to use for education was designed for optimizing processes. Optimizing of the selected functions is performed with genetic algorithms whose parameters (the number of variables, lower limit, upper limit) with designation entered. Obtained results are presented to user as both numerically (suitability value, roots etc.) and graphically (suitability depending on iteration or on cross rate etc.). Hence, the efficiency of genetic algorithms and parameters can be obviously seen.

II. GENETIC ALGORITHM

Genetic Algorithms are a part of evolutionary calculation. This area is a developing branch of artificial intelligence. This algorithm emerged as a result of adjusting the occurring biological events on genes to today’s problems. John Holland came up with genetic algorithms first, then his students and colleagues developed. Holland were studying on machine learning, and by having been effected by Darwin’s evolution theory, he thought about performing the genetic process of the living in computer environment and he saw a community could generate successful new individuals by passing genetic processes such as proliferation, mating, mutation etc. in such structures instead of developing the learning ability of only one mechanical structure. He performed his studies based on natural selection and genetic evolution to research and to find optimum; during the process, it was modeled by computer softwares in finding the optimum and machine learning by taking an individual adapting his/her environment and becoming more suitable in biological system, as an example [7].

Algorithm uses an initial density (population) that consists of the present solutions in research space. This initial density is developed repeatedly by natural selection and reproduction processes in every generation. The most suitable it means the most qualified individual of the last generation is the optimal solution for the problem. This solution, may not always be the optimum, but it is absolutely the nearest solution to optimum [8].

Genetic Algorithm, is effectively used in problems which are impossible to solve by classical optimization methods or in the solution of the problems whose solution time increases with the increase of magnitude, and its suitable structure for the computers capable of parallel processing provide it to be an attractive alternative for the solutions of time consuming problems to solve in short time. Some application areas of Genetic Algorithm are given below:

- General Application Areas
  - Optimization Problems
  - Automatical Programming and Information Systems
  - Mechanical Learning
  - Economical and Social System Models
### TABLE I
GENETIC ALGORITHM FLOWCHART, STEPS AND DESCRIPTION

<table>
<thead>
<tr>
<th>Flowchart</th>
<th>Steps of Algorithm</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Initiation: A random population with n chromosome.</td>
<td>Step 1. In this step, it is started by determining the number of individuals in the population. Generally, a size of 100-300 is suggested.</td>
<td></td>
</tr>
<tr>
<td>Create initial population</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculate fitness values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selection, Crossover, Mutation, Test</td>
<td>Create new generation</td>
<td></td>
</tr>
<tr>
<td>Is it optimal value?</td>
<td>Y</td>
<td>Stop</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Suitability: x-each chromosome in the population is evaluated in f(x) function. | Step 2. The function which finds how good chromosomes are, is named as suitability function. Finding the chromosome by operating this function is named as calculation. This function is the base of genetic algorithm. The only part that works specifically to problem is this function in genetic algorithm. Mostly, the success of genetic algorithm depends on the productivity and sensitivity of this function. |

3. New Population: Selection, crossing, mutation and acceptance steps are repeated until the new population generated. | Step 3. Chromosome matching is done according to suitability value of chromosomes. New chromosomes are produced after the processeses below. a. Selection: Two parent chromosome are chosen. To make this selection, Roulette wheel selection, tournament selection methods are present. b. Crossing: They are matched to generate new generations with crossing possibility. If there is no crossing, children will be the same as their parents. c. Mutation: new generation in every locus are mutated by the mutation possibility. d. Acceptance: New generation is added to new population. |

4. Substitution: It is used to operate new population algorithm again. | Step 4. A constant population is provided by removing the old chromosomes. |

5. Situation: If the new population is enough, it stops. This is the best solution found ever because of saving the best individuals during the calculating population. | Step 5. The success of the new population is found by calculating all the chromosomes. |


- Common Applications in Business
  - Finance
  - Marketing
  - Production

Flow of Genetic Algorithm is quite easy. Many parameters and adjustments are accomplished in different ways for different problems. The steps for solutions of Genetic Algorithms and description of them are given in Table I [9].
III. SIMULATIONS

In this study, a graphical interface is designed to calculate the optimization of function roots that were determined by using MATLAB [10]. This programme is opened from the panel named function selection, function is chosen from the menu and the function which will be optimized is selected. Roots of the function and suitability value are calculated by genetic algorithm method. The main screen of the application is shown in Fig. 1 The first running version of the programme is shown in Fig. 2. Also mathematical functions used in the operation of the simulation is shown in Table II.

<table>
<thead>
<tr>
<th>Name of Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rosenbrock</td>
<td>100(x₂ - x₁)² + (1-x₁)²</td>
</tr>
<tr>
<td>Function 1</td>
<td>x₁ - x₂ + 2 * x₁² + 2 * x₄ * x₂ + x₂²</td>
</tr>
<tr>
<td>Function 2</td>
<td>exp(x₁² + 5 * x₂) + x₁² + 80 * x₂</td>
</tr>
<tr>
<td>Function 3</td>
<td>3 * sin(30 * x) + 2 * cos(50 * x)</td>
</tr>
<tr>
<td>Function 4</td>
<td>(x₁ - 2)² + (x₁ - 2 * x₂)²</td>
</tr>
<tr>
<td>Function 5</td>
<td>10 * x₁² + x₂²</td>
</tr>
<tr>
<td>Function 6</td>
<td>3 * x₁² + 4 * x₂² - 6 * x₄ + 16 * x₂² + 19</td>
</tr>
<tr>
<td>Function 7</td>
<td>3 * (x₁ - 0.5)² + 7 * (x₂ - 0.75)²</td>
</tr>
<tr>
<td>Function 8</td>
<td>3 * x₁² + 3 * x₂² + 4 * x₄ * x₂ + 2</td>
</tr>
<tr>
<td>Function 9</td>
<td>3 * x₁² + 2 * x₄ * x₂ + x₂²</td>
</tr>
<tr>
<td>Function 10</td>
<td>x₁² + x₂² - 2 * x₁² - 4 * x₄ * x₂ - 2 * x₂²</td>
</tr>
<tr>
<td>Function 11</td>
<td>2 + (x₁ - 1)² + (x₂ - 1)²</td>
</tr>
<tr>
<td>Himmelblau</td>
<td>2 * x₁² + 4 * x₁ * x₃² - 3 - 10 * x₁ * x₂ + x₂²</td>
</tr>
<tr>
<td>Function 12</td>
<td>8 * x₁² + 4 * x₄ * x₂² + 5 * x₂²</td>
</tr>
<tr>
<td>Function 12</td>
<td>1.2 + 0.1 * x₁² + ((0.1 + 0.1 * x₂) / x₁²)² + 10 / (x₁ + x₂)</td>
</tr>
<tr>
<td>Peaks</td>
<td>sin(x₁) * sin(x₂) * exp(-x₁² - x₂²)</td>
</tr>
<tr>
<td>Function 14</td>
<td>x₁ * exp(-x₁² - x₂²)</td>
</tr>
</tbody>
</table>

In calculation with genetic algorithm, the number of variables, lower and upper limits of root intervals should be entered by keyboard. Also, parameters of genetic algorithm can be changed and then applied. The changeable parameters of genetic algorithm are size of population, scaling the suitability (fitness) function (rank, proportional, hill, linear changee), selection function (Stochastic uniform, increasing, uniform, roulette, tournament), mutation function (gaussian, uniform, adaptive), crossingover function (distributed, single-point, two-point, search, heuristic, arithmetic) and crossing over rate.

In the first simulation Rosenbrock function

\[
y = 100(x₂ - x₁)² + (1 - x₁)² \quad (1)
\]

optimization was occurred (Fig. 3). In the second simulation

\[
y = x₁ * exp(-x₁² - x₂²) \quad (2)
\]

roots of an exponential function were optimized (Fig. 3). These functions have two different roots. Research space was formed between [1, 10] interval to find the roots.
Parameters of genetic algorithms were adjusted as below:

- Population size: 20
- Scaling suitability functions: Rank
- Selection function: Stochastic uniform
- Mutation function: Gaussian
- Crossing-over function: Distributed
- Crossing-over rate: 0.8

The change in suitability function and roots can easily be detected in Simulator by changing parameters of genetic algorithm. The effect of the change in crossing-over rates on suitability value can be seen in Fig. 3. To obtain the values that would give the best result, the crossing-over rates were changed and its effects were investigated during the iteration. The best individuals are in the interval of 0.7 ve 0.9 of crossing-over rate.

![Fig. 3 Application examples](image)

**IV. CONCLUSIONS**

In this performed study, an interactive graphical interface programme which can optimize the functions by genetic algorithm was designed. With this education-aimed programme; functions optimization operations can be performed more easily and more effectively, effects of parameters can be investigated, and the results can be observed both numerically and graphically. As a next study, it is aimed to investigate the diversity of functions and algorithm type.

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A Hybrid Genetic Algorithm for Mobile Robot Path Planning Problem

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Abstract— This paper proposes an algorithm to solve the problem of path planning for a mobile robot in a static environment with obstacles. The proposed algorithm is a Hybrid Genetic algorithm (HGA) which includes Genetic and Dijkstra algorithms together. The genetic algorithm (GA) is preferred since the structure of robot path planning problem is very convenient to apply genetic algorithm’s coding and operators such as permutation coding, crossover and mutation. GA provides diversification while searching possible global solutions, but Dijkstra algorithm makes more and more intensification in local solutions. The simulation results show that the mobile robot can plan a set of optimized path with an efficient algorithm.

Keywords— Robot path planning, genetic algorithm, Dijkstra algorithm.

I. INTRODUCTION

Robot path planning (RPP) is a popular issue in mobile robotics. An intelligent robot must be able to move by itself from a start location to a target location without collision with obstacles. Therefore an important research subject in this field is navigation of autonomous mobile robots, which is to find a globally optimal path from a starting point to a target in a given environment and at the same time avoid collisions. Moreover, the “optimal” here means that the path must satisfy some criteria like length of the path is the shortest, or energy consumption of robot is the lowest or needed time to reach a target is minimum etc.

There are several search algorithms for the shortest path problem such as the A* algorithm, the Dijkstra algorithm and the Bellman–Ford algorithm [1], [2], [3]. These algorithms ensure to find a shortest path. However, these algorithms are not effective for large dimensioned problems because of with low searching efficiency and high computational time.

In recent years, many researchers have studied the robot path planning on various intelligent methods, such as particle swarm algorithms [4], immune algorithm [5], neural networks and ant colony algorithm [6], differential evolution [7], and so on. Additionally, genetic algorithm is one of the popular metaheuristic algorithm for RPP [8] problem.

The GA was introduced by Holland [9] in the early 1970s. It imitates the evolutionary processes such as inheritance, mutation, selection and crossover. Also for centuries, there is a biological evolution in the world and GA simulates it by using iterative process. The GA has a wide using area in many types of problem thanks to easy adaptation and high high-performance computing.

In this paper, a Hybrid Genetic algorithm (HGA) is proposed to solve RYP problem. The aim is to combine the global search capability of genetic algorithm and local exact solution capability of the Dijkstra algorithm to get faster solution for shortest path problem. In numerical simulations, 20x20 and 50x50 environments with obstacles are solved to get shortest distances and, Dijkstra, genetic and proposed hybrid genetic algorithms are compared in Table for iteration number and required time, respectively.

The paper is organized as follows. Section 2 describes the method of grid modeling, Dijkstra algorithm and genetic algorithm. Section 3 describes the proposed hybrid genetic algorithm for the robot path planning problem. Section 4 presents the numerical simulations on robot path planning. Section 5 presents concluding remarks.

II. PRELIMINARY WORKS

A. Grid modeling

The method was proposed by the Howden in 1968, and its primary task is to construct a path grid map according to the environment. Given environment is divided into small units and a robot goes one unit with one move. Two kind of grid can be described in method which are free and obstacle grid. In black grid’s mean is obstacle, white grid’s mean is free namely movable area. In real environment sizes of obstacles can be different and they can occupy lower one or more grids. A robot cannot enter an obstacle even if the obstacle is very small.

The grid can be divided into intermediate grid and boundary grid. For intermediate grid, robot may have eight directions for the next motion. Such as up (7), down (2), left
(4), right (5), right-up (8), right-down (3), left-up (6) and left-down (1). Fig. 1 shows the motion direction of the robot and Fig. 2 shows a 10x10 grid map. And for boundary grid, it has to subtract inaccessible directions. Robot must avoid obstacles to select an optimization motion path moving to the target position [10].

![The motion direction of the robot.](image1)

**B. Dijkstra Algorithm**

Dijkstra algorithm is introduced by W. Dijkstra in 1959 [1]. It is one of the most common used algorithm for solving the shortest path problem. It is possible to find a shortest path from starting point to any node by Dijkstra Algorithm. If the performance criterion is different from distance, it is also useful for measuring other criteria such as time, cost and energy. Dijkstra algorithm guarantees the shortest path which is generated. Dijkstra algorithm is a useful method for not only robot path planning but also network optimization, transportation, logistics, electronics and other fields. However, it takes much time while solving large problems and this is a disadvantage for this method.

![10x10 grid map](image2)

**C. Genetic Algorithm**

Genetic algorithm combines genetics and computer science. GA is biology inspired, population based, has memory, stochastic and greedy algorithm.

Here are a few basic concepts of genetic algorithm:

**Chromosome and Coding:** In order to use genetic algorithm, feasible solution of the problem needs to be coded into symbol string which have fixed structure. The string is called chromosome. Each bit of the string represents a gene.

**Population:** the total number of chromosomes in each generation is called population. A population contains a set of feasible solutions in current generation.

**Fitness:** Each chromosome corresponds to a feasible solution, and each solution corresponds to a function value. This function value is used to measure the environmental adaptability of a chromosome.

Select: Select operation can select adaptable individual in current population, so that adaptable individual has the opportunity to breed the next generation as a parent.

Crossover: Crossover operation can produce new individual, the new individual combines the characteristics of parents.

Mutation: mutation operation can change one or a number of genes in a fixed probability. The purpose of mutation is to create new chromosomes for next generation.

The process of genetic algorithm: determine the encoding rules, generate a population randomly, calculate fitness function and selection probability, select, crossover, mutation, loop all the operation above until it meet the terminate conditions [11].

**III. PROPOSED HYBRID GENETIC ALGORITHM**

In this section, proposed algorithm steps are explained in detail.

**A. Problem Description**

A road from starting node (S) to target node T is an (S, T) path, the length of a path is the sum of the length of the edges \(|p_{i+1}\|\) in one path. Ro bot path problem is to find the path from S to T, where the length of the path is minimum one at the same time avoid obstacles. A candidate path for robot path planning is denoted by \(P=\{p_1, p_2, ..., p_n\}\)

where \(p_i\) denotes the \(i\) th node of the planned path \(P\), \(n\) denotes the number of without obstacle nodes in a given environment and \(p_1=S\) and \(p_n=T\).

Total length of the path can be obtained by equation (1):

\[
f(p) = \sum_{i=1}^{n-1} |p_ip_{i+1}|
\]

where \(|p_ip_{i+1}|\) is the length of the path segment \(p_ip_{i+1}\) which is computed by Euclidean distance and it can take value \(\sqrt{2}\) or 1. Additionally \(f(p)\) is objective function of given path which we try to minimize.

**B. Chromosome encoding and initial population generation**

For a given graph, each node will be coded as a gene sorted by the node number. A chromosome includes path information and sequence of genes. In this paper, permutation coding is used for encoding. Nodes take place as combinatorics in a solution if a node is visited as an example shown below:

\[1\rightarrow 9\rightarrow 16\rightarrow 17\rightarrow \ldots \rightarrow 71\rightarrow 79\]

The first and end nodes must be in the solution, indicating the starting node S and target node T. There is no need to the test chromosome if the path is connected. Producing initial solution strategy guarantees that all the nodes which are included solution are connected. In other word, length of a
chromosome is equal to number of passed nodes. Therefore, there is a remarkable decreasing usage of memory for a chromosome and computation time. Cross-over and mutation operators are modified because of different length of chromosome which are shown next subsections.

While generating initial solution, a node is selected (initial gene of solution is starting node) and other neighbors are found which are connected to the selected node. Randomly selected a neighbor node is added to solution. This procedure is repeated until reached target nodes. Additionally, generating strategy checks if a node is visited before. Table 1 shows generating a chromosome for given map in Fig. 3.

<table>
<thead>
<tr>
<th>Exist Solution</th>
<th>Candidate Nodes</th>
<th>Randomly Selected Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2, 9</td>
<td>9</td>
</tr>
<tr>
<td>1, 9</td>
<td>2, 3, 15, 16, 17</td>
<td>15</td>
</tr>
<tr>
<td>1, 9, 15</td>
<td>16, 24, 25</td>
<td>25</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>1, 9, 15, 23, ... , 71</td>
<td>62, 79</td>
<td>79</td>
</tr>
</tbody>
</table>

For example:

\[ \text{intersect}(x_1, x_2) = 9,44 \] except for 1,79

For randomly selected node which is 44. The new chromosomes (children):

\[ x_1 = 1.2.9,17,18,19,27,36,44,52,61,68,76,77,78,79 \]
\[ x_2 = 1.9,16,25,33,41,42,43,44,53,54,62,71,79 \]

**Mutation:** The parental chromosome is chosen according to selection method. The parents start and target nodes are not mutated. The mutation operation is done by selecting a random node in the parent according to mutation probability. The two nodes which are coming before and after selected nodes are detected. Mutation operator tries to find a different node to connect these two nodes. If these two nodes connect to each other directly, selected node is deleted from the solution. An example for mutation operator can be shown as

\[ [1,2,9,17,18,19,27,36,44,53,54,62,71,79] \]

where selected node is 36, node 27 is coming before and node 44 is coming after node 36. Neighbor nodes are from 27 and 44 are:

27→19,20,26,28,34,35,36
44→34,35,36,43,52,53

where node 34 and 35 are common neighbors for nodes 27 and 44. Randomly selected one of these nodes is exchanged with node 36. The mutated chromosome is

\[ [1,2,9,17,18,19,27,35,44,53,54,62,71,79] \]

**C. Fitness function**

Fitness function must be calculated for each of chromosomes. The function is the sum of the length of the edges \(|p_{i_{start}}|\) in a path which is given equation (1).

\[ \text{Fitness function} = \sum |p_{i_{start}}| \]

**D. Select, Crossover and Mutation**

**Select:** For a given population \(X\) and fitness of each chromosome is \(f(X)\). The number of chromosome randomly selected in \(X\) is \(M\) and the best one is selected by using tournament selection for reproduction. In this work \(M\) is assumed 2 for the tournament selection.

**Crossover:** For the given chromosome \(x_1, x_2\) which are parent, their intersected nodes \(\text{intersect}(x_1, x_2)\) are found except for starting and target nodes (1,79) and one of the found nodes is selected randomly. This node is called as crossover point and single point crossover is used. A crossover is done at the selected node.

For example:

\[ x_1 = 1.2.9,17,18,19,27,36,44,52,61,68,76,77,78,79 \]
\[ x_2 = 1.9,16,25,33,41,42,43,44,53,54,62,71,79 \]

\(\text{intersect}(x_1, x_2) = 9,44\) except for 1,79

**E. Dijkstra Algorithm**

In this algorithm, after standard Genetic algorithm steps are applied in each iteration, Dijkstra algorithm is conducted to all individuals of current generation between two points (randomly selected) which are close to each other. Thus, the proposed algorithm is able to find rapidly a nearly optimum path for a mobile robot without collides with static obstacles.

After generating initial population, selecting, crossover, mutation and Dijkstra algorithm are applied to each generation until termination criteria is achieved.

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Fig. 3 Grid map for initial solution procedure.
IV. NUMERICAL SIMULATIONS

Computer simulation environment includes a notebook computer with Intel® Core™ i7-4712 MQ CPU @ 2.30 GHz, 8 GB RAM. The planned path is shown in Fig. 4.

The simulations are conducted with 20x20 and 50x50 environments with random obstacles. The 20x20 grid map example, which includes 400 nodes and 318 of total nodes are free and 82 nodes are obstacles. At the same time the 50x50 grid map example, which includes 2500 nodes and 2080 of total nodes are free and 420 nodes are obstacles. The resulting paths with HGA are shown in Fig. 4 and Fig. 5, respectively.

The performances of the algorithms are given in Table II. These algorithms produce same fitness value for 20x20 and 50x50 environments as 59.8701 and 72.8112, respectively. However, the iteration number and required time change with the algorithm therefore they are given in Table II. According to the performances, the proposed HGA is always better than the conventional genetic algorithm. However, for small size problem, the Dijkstra algorithm provides the solution in a shorter time. Note that when the problem size increased, the Dijkstra algorithm requires larger time to solve which is seen in given Table.

V. CONCLUSION

In this paper, RPP problem is solved with a novel Hybrid Genetic algorithm (HGA). Simulation results show that the proposed method provided the same solutions with lower iteration number and required time for 50x50 environment. It is seen that the proposed method is especially suitable for the large dimensional RYP problems in future applications. The algorithm is planned to be used in real-time with a laboratory mobile robot.

REFERENCES

DIFFERENT DUTY CYCLE RATIO AND BRIGHTNESS OF VISUAL STIMULI CHANGE TO STEADY STATE VISUAL EVOKED POTENTIAL RESPONSE

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Abstract—Stimuli types are very crucial for the performance of electroencephalogram (EEG) based brain computer interface (BCI) systems. This study aims to investigate methods for obtaining higher information transfer rate (ITR) through duty cycle and brightness variation of visual stimuli which have high frequency for steady state visual evoked potential-based BCI. Although previous studies were concentrated on either duty cycle or brightness of stimuli separately, our study focused on the change of duty cycle ratio and brightness of stimuli at the same time. Duty cycle values of 40%, 50%, and 60% were used. During the experiment, 16 flickering stimuli were used on liquid crystal display. Participants gazed to the flicker which had frequency of 15 Hz. Canonical correlation analyses (CCA) was used for channel selection and frequency detection. According to the CCA, the maximum average accuracy of the experiment was 92.54% when the frequency of flicker was in beta band and its duty cycle was 40% with a brightness tuning wave. Under the same conditions stated above, average ITR was improved 16.1% according to the most commonly used flicker model which is square wave and has 50% duty cycle.

Keywords—Brain Computer Interface, EEG, Human-Computer Interaction and Systems, Steady State Visual Evoked Potential

I. INTRODUCTION

Brain computer interface systems gives chance users to communicate with external devices without using peripheral neuromuscular systems. There are many brain imaging methods, such as electroencephalography (EEG), functional magnetic resonance imaging(MRI), magnetoencephalography (MEG), and and near-IR spectroscopy (NIRS) have been adopted BCI systems [1], [2]. In BCI systems, the commands are identified by extracting Electroencephalograms (EEG) which measures the electric field generated from brain. EEG based BCI systems is preferred for other BCI system because of practical use, low cost, good response, portability [3].

There are some most common approaches to EEG based BCI systems that are P300 potentials, event-related (de)synchronization (ERD/ERS), slow cortical potentials, oscillatory activity, and visual evoked potentials (VEPs) [4-7]. The Steady state visual evoked potential (SSVEP) is a brain response modulated by the frequency of repetitive visual stimulus [8]. SSVEP is known to be most prominent at the occipital location over the visual cortex.

The SSVEP-based BCI has been preferred due to high signal to noise ratio and high information transfer rate (ITR) according to other BCI approaches [9]. Moreover, the SSVEP has a short training and response time [10].

The term of Information transfer rate is a very significant unit that has been used to evaluate overall performance of BCI systems [11]. Types of stimulus have very important role for high SSVEP response that related on ITR that can be described as information transmitted in bits per minute (bpm).

Thus, there are many studies for investigate best stimuli type for SSVEP based BCI systems. Wu (2010) [12] proposed that %40 duty cycle ratio when the flicker was 10 Hz, SSVEP response reached highest value. Shyu et al. (2013) [13] made a SSVEP-based BCI system that using FPGA, which based on duty cycle ratio. Manyakov et al. (2013) [14] showed that sampled sinusoidal stimulation enabled for encoding more targets and elicited SSVEP response with a significantly better phase stability. Moreover, Chen et al. (2014) [15] presented sampled sinusoidal stimuli for SSVEP response. According to result of this study, ITR value was reached the highest one when the flicker was at low and high frequencies.

In recent years, researchers presented many approaches to make and develop SSVEP based BCI systems.

In this study we aimed to investigate effect the change of duty cycle ratio and brightness of stimuli at the same time, although previous studies were concentrated on either duty cycle or brightness of stimuli separately.

II. MATERIAL AND METHOD

Five healthy participants (males, mean age 29 years, corrected to normal vision) joined experiments in this study. Participants didn’t have any history of epilepsy and psychiatric disorders.
A. Experimental Structure

In the experiments, SSVEP stimulator software was created by C# programming language. This SSVEP stimulator software is portable and functional. As shown in Figure 1, according to the main menu of software, colour of flickers and background, size of flickers, frequencies of flickers, quantity of flickers, brightness of flickers, duty cycle ratio of flickers could be changed by users.

The EEG were acquired from the scalp of the participants via 19 Ag/Ag-Cl electrodes. EEG electrodes placed according to the international 10-20 system. During the study Nihon Kohden Neurofax EEG-1200 EEG device was used for EEG data acquiring.

The reference electrodes were placed over the left and right earlobes. Ground electrode was on the intercilium point (the space between the eyebrows). EEG data were sampled at 500 Hz.

B. Stimulation Types

In this study, we focused on the change of duty cycle ratio and brightness of stimuli at the same time. Duty cycle values of 40%, 50%, and 60% were used. As shown in Figure 2, we used a square pulse that was presented as Type I signal. \( T_{\text{period}} \) is denoted the pulse cycle duration which is total of \( T_{\text{on}} \) and \( T_{\text{off}} \) that are defined stimuli on and off cycle durations respectively. \( R_{\text{duty}} \) is denoted duty cycle ratio which is presented in Equation 1.

\[
R_{\text{duty}} = \frac{T_{\text{on}}}{T_{\text{on}} + T_{\text{off}}}
\]  

![Fig. 1 The SSVEP stimulator software setting menu](image1)

![Fig. 2 Type I signal: stimulation signal is at square pulse.](image2)

In this study, we presented a novel stimuli type that variation of brightness of pulse as shown in Figure 3. During the “on” status, flicker’s brightness was on the increase within the equal time span of \( T_{\text{on}} = 9 \) till it reached to the peak value of Type I signal, after increased, it was on the decrease till it reached to “off” status within the equal time span.

![Fig. 3 Type II signal: variable brightness when the flicker is on status](image3)

C. Experimental Steps

During this study, as shown in Figure 4, 16 flickering stimuli were showed on liquid crystal display (LCD). Participants were seated 50 cm away from LCD with a refresh rate of 60 Hz.

![Fig. 4 The 16 Flickers on LCD](image4)

16 stimuli were 150 pixels x 150 pixels arranged in a 4 x 4 matrix.

Participants gazed to the flicker which had frequency of 15 Hz. During the experiment, participant gazed to flicker 6 seconds, after that 4 seconds for resting time. 10 trials were
examined by each participants for every duty cycle ratio and signal types that include type I and type II signals.

D. Data Analysis

Canonical correlation analysis (CCA) is a multivariate analysis that presented by Lin[16]. According to the Equation 2 CCA investigates the maximum correlation between the two variables.

\[
\max \rho (x, y) = \frac{E[x^T y]}{\sqrt{E[x^T x] E[y^T y]}} = \frac{E[W^T_x X Y^T W^T_y]}{\sqrt{E[W^T_x X X^T W^T_x] E[W^T_y Y Y^T W^T_y]}}
\]

Equation 2

The weight vectors \(W_x\) and \(W_y\) to maximize the correlation between, linear combinations, \(x\) and \(y\) by Equation 2. \(\max \rho (x, y)\) denoted as the maximum canonical correlation of the \(W_x\) and \(W_y\). As shown in Figure 5, shows the CCA model was presented. According to the model, \(X\) denoted EEG signal, \(Y_f\) denoted the reference signal.

![Fig. 5 The CCA Model](image)

The reference signals were artificially generated with sinus and cosines waves of the flicker’s frequency and their harmonics by Equation 3.

\[
Y_f = \left( \begin{array}{c} \sin(2\pi f_t) \\ \cos(2\pi f_t) \\ \vdots \\ \sin(2\pi H f_t) \\ \cos(2\pi H f_t) \end{array} \right), \quad t = \frac{1}{F_s} 2 \frac{F_s}{F_s} \ldots \frac{N_t}{F_s}
\]

Equation 3

Sixth-order Butterworth band pass filter with 5 and 20 Hz cut-off frequencies was applied. After that CCA method was used.

\(CW_k\) showed that brain frequency map. According to the result, O2, O1, O2 EEG channels were used for data accuracy.

ITR is a very significant unit that has been used to evaluate overall performance of BCI systems.

ITR can be described by following Equation.

\[
Bits_{Command} = \log_2 N + P \log_2 P + (1 - P) \log_2 \left(\frac{1 - P}{N - 1}\right)
\]

Equation 4

\(ITR = \frac{Bits_{Command}}{CTI} \times 60\)

Where \(P\) denotes accuracy of classification, \(N\) denotes total stimuli, CTI denotes command transfer intervals.

In this study, CTI is 6 seconds because of gaze time during in one trial.

III. RESULT AND DISCUSSION

Experiments were completed without any problem. Table 2 shows that outcome of the experiment average accuracy and the average ITR.

<table>
<thead>
<tr>
<th>Duty Cycle Ratio</th>
<th>Signal Type</th>
<th>Average Accuracy (%)</th>
<th>Average ITR (bpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td>Type I</td>
<td>88.03</td>
<td>30.04</td>
</tr>
<tr>
<td>40%</td>
<td>Type II</td>
<td>92.54</td>
<td>32.89</td>
</tr>
<tr>
<td>50%</td>
<td>Type I</td>
<td>84.98</td>
<td>28.32</td>
</tr>
<tr>
<td>50%</td>
<td>Type II</td>
<td>90.08</td>
<td>31.42</td>
</tr>
<tr>
<td>60%</td>
<td>Type I</td>
<td>80.68</td>
<td>25.24</td>
</tr>
<tr>
<td>60%</td>
<td>Type II</td>
<td>83.28</td>
<td>26.92</td>
</tr>
</tbody>
</table>

Average ITR was improved 16.1% according to the most commonly used flicker model which is square wave and has 50% duty cycle. As shown in Figure 6, the highest average accuracy was reached when the flicker’s duty cycle ratio was 40% and type II signal.

![Fig. 5 The difference of average ITR and improved ratio](image)
improving the accuracy, and (3) decreasing the command transfer intervals. In this study, we aimed to improve ITR value by increasing the accuracy with a new created signal type for stimuli.

We applied statistical test to the results shown in Table 2 to examine whether the differences in the classification accuracy were significant depending on the duty cycle and flicker type. A one-way analysis of variance (ANOVA) was conducted on the classification of accuracy for each flicker models, indicating that the difference was considered significant at the p-value < 0.05.

CONCLUSION

It can be concluded that previous studies mainly focused on the effects of either duty cycle pulses ratio or brightness of stimuli separately. But, we aimed to investigate the effects of both parameters at the same time. We optimized signal type and duty cycle ratio.

Despite the fact that there is not enough knowledge for characteristic attitude of brightness and duty cycle parameters which are very important for ITR and accuracy in SSVEP-based BCI systems, in this study, for these parameters remarkable results have been accomplished.

ACKNOWLEDGMENT

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REFERENCES


Topology Control in Mobile Wireless Sensor Networks

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Abstract—Topology control is a set of strategies and actions that aim to improve energy efficiency, lifetime and reliability of the networks. One of the most effective methodologies is topology reduction, which is a part of the overall topology control process. Topology control process is usually considered under two phases: construction and maintenance. This hard work would even be harder for mobile ad-hoc sensor networks, those consist of devices with limited capabilities and continual independent movement. In this work, we made our efforts to find out effects of mobility of the nodes in an ad-hoc wireless sensor network on network parameters, by using different pre-defined topology control protocols. Thus, we made simulations using an experimental simulator, called Atarraya. Furthermore, we measured the performance of each protocol and compared the outcomes in order to find the best topology control strategy. Lastly, possible solutions to the uncovered problems are proposed.

Keywords—Ad-hoc wireless sensor networks, mobility, topology control, wireless sensor Networks, simulation

I. INTRODUCTION

After conventional wide area and local area networks (LAN), nowadays, personal area (PAN) and body area networks (BAN) are becoming more and more popular in applications of industry, commerce and science [1]. Along with their abilities and advantages, these networks also have their own challenges [2]. For instance, they usually include nodes on the move or at least nodes that can be relocated. Hence, the newest solutions in the interconnecting network technologies have to deal with the mobility cases as well.

From that starting point, in order to build the rest of the work on it, we’ve presumed a set of use cases, called as scenario. Although the results wouldn’t be directly related to the scenario, it would help us to make some decisions. Our scenario based on an indoor working environment including unsynchronized moving people, who are representing BAN or PAN networks by holding or even wearing wireless sensor devices. Most applicable realization is hospitals, but also mines, schools, prisons, sport fields and in a wider point of view, zoos. Additionally, we suppose a continuous communication is required in our scenario.

II. PREVIOUS WORKS

While building our background, we found out several studies about topology control [3] and maintenance [4] in wireless sensor networks. And of course we used valuable information provided in these works. But we couldn’t find a comparative study to refer, which focuses directly on mobility case. For instance, in [5] authors present a comparative study similar to ours, however they used fixed nodes and totally excluded the mobility case, which is our main focus. In their work, Laré et al. [6] introduce a protocol (Cascading information retrieval by controlling access with distributed slot assignment - CICADA) designed for mobility cases and present a detailed analysis, but their study is not comparative. Reluctantly, we could not include CICADA and CICADA-S (a secure version proposed later [7]) in our work because of the limitations of the tool we have used.

The reason of that scarcity is that wireless sensor networks is a quite new area, and mobility in these networks is even a newer aspect. Most of the previous works in this area focused on higher layer architecture, like routing and forwarding protocols. Here, we worked on a lower level relationship between nodes by reducing the number of links between them.

The simulator we used, namely Atarraya, was also introduced in a previous work [8] and still under development with new features. A side note: Mobility wasn’t even included in our simulation tool Atarraya’s first version, here we used version 1.3.

III. ASSUMPTIONS & DECISIONS

To find key points, we had to choose optimum preferences and had to limit our angle of sight. Our very first assumption about the concept is a scenario as described in introduction. Before going on, we assume the undetermined smallest integer time unit in Atarraya as milliseconds.

A. Algorithms

For the evaluation, we wanted to choose topology control and maintenance algorithms, which have different approaches as possible and tried to avoid similar algorithms. So, we have chosen A3, energy efficient connected dominating set (EECDS) and Kneigh tree protocols for topology construction. Detailed descriptions of these protocols can be found in [9, 10]. Then we considered dynamic global time-based topology recreation (DGTTRec), static global time-based topology rotation (SGTTRot), and HGTTRec and rotation (HGTTRecRot) for
initialized by the sink. Excluded from that ratio. Here, core network means the network basically, the nodes out of the core network coverage are setting the topology time interval 1 s. This interval theoretically provides 600 m of moving field mentioned above, using Normal distribution with sigma = 100. When simulation starts, nodes can leave this initial deployment area and can move in the whole observation field, or even may leave that area.

Our test field represents a surrounded area like a hospital, a factory or an office environment. It can also be an open-air field but we mostly focused on an indoor environment. Hence, we placed 30 nodes (+1 initializer sink), which makes a sparse network. This number may be increased until around 100 without distorting the test outcomes. Numbers bigger than a few hundred may cause the simulator to slow down, stutter or act inconsistently.

We used a realistic communication range of 100 m, which is typical for ZigBee, Bluetooth Class 1 and Wi-Fi b/g/n [11]. We set sensing area to 20 m but, in this work, it wasn’t important in our point of view, so we didn’t take care of sensing range and sensed data.

As total simulation time for topology maintenance tests, we considered 60 seconds. It was enough to see effects of mobility, plus we had some limitations about our movement model (see below). This interval theoretically provides 600 m of moving range to each node (see below). Thus, we also decided resetting the topology time interval 1 s.

We assigned 1000 mJ total energy stock to each node and used simple energy model of the software. We also used simple communication model. Another assumption was 0 bit error rate (BER) value, means communication link is perfect. Effect of BER is subsequently analyzed.

Finally, a connectivity metric is defined to measure the performance of the protocols in the sense of physical and logical connectivity. This metric is considered as a percentage of nodes (directly or as multi-hop) connected to the sink node among all the nodes in the coverage of the core network. Basically, the nodes out of the core network coverage are excluded from that ratio. Here, core network means the network initialized by the sink.

\[
C(\%) = \frac{\text{# of nodes connected to network (t)} - 1}{\text{# of nodes in the range of network (t)} - 1}
\]

Obviously, this connectivity metric is a function of time (and movement), so it will also represent robustness and sustainability of the protocols. By the way, this metric can be the most important information to determine the usefulness of a topology control protocol depending on the scenario.

C. Movement Model

We designed a movement model in order to provide mobility to nodes in the simulation. There are two main limitations to consider: First, movement model should be realistic, thus results will be useful in further works and industrial applications. Second, simulation tool Atarraya is an (very useful but) experimental tool and has limited capabilities in this manner [8].

So, our movement model consists of these features: Simple random walk mechanism for each node with sleep time 100 ms and step size 1 m, without surrounding limits (fences) on the field. This makes 10 m/s and is 5 to 10 times faster than the average human walking speed, which is around 1 to 2 m/s [12]. We used that increased value to see the effects of mobility more clearly. By using randomness, movement of nodes is non-deterministic to each other and no predictions can be made besides the step size.

Another characteristic of the model is spreading. All nodes in a very long period of time, eventually, will leave the test field since there is no fence. This is not an intended behavior but due to program limitations, it is not possible to prevent this. Only the simulation time can be limited at an optimal time period. However, this behavior allows us to see what happens when some nodes leave the area, which can be a realistic scenario.

IV. RESULTS

We first evaluated the topology construction protocols, by starting the simulation without a time limit. 30 Nodes and 1 sink node are deployed in the field as described above. Simulation ended up after a successful topology creation. All values given in this section are average of 10 measurements.

![Fig. 1 Durations of the initial topology construction period](image)

Fig. 1 gives the time passed until the successful creation for each protocol. Here, it is very clear that, tree based A3 and Kneigh tree protocols are much faster than dominating set based EECDS and k-connected k-dominating set (CDS-K).
Due to the mobility of the nodes, it would be better to use faster protocols.

Total message traffic can be seen in Fig. 2, which stands for the total number of sent and received messages in the network, between all 31 nodes. Here, A3 and Kneigh tree produce significantly less traffic than EECDS and CDS-K. Lower values would be preferable because sending and receiving more messages will cost more energy, processing power and bandwidth.

Fig. 3 shows total energy consumed among whole network. These values are some of the consumptions of all 31 nodes. As expected from the message traffic results, A3 and Kneigh tree consume much less energy from EECDS and CDS-K. While Kneigh tree consumes least energy, EECDS becomes the last preferable with the highest consumption, which is 4 times more than A3 and 30 times more than Kneigh tree.

A very important statement; all these protocols complete their work by constructing the topology much faster than the movement speed of mobile nodes. Our movement model proposes a 5 m step size per 500 ms. But, here the slowest protocol, CDS-K, requires 58.42 ms. Even when we change our movement model (unless we set an unrealistic super speed like 100 m step size per 10 ms or so), the results are (almost) the same as stationary ad-hoc wireless sensor networks’ results.

So, information given until here, are not enough to uncover the effects of the mobility in that network. Because, if there were no mobility, results would be very close, and also network operating time should be much higher than construction time. Over and above, we have to check topology maintenance simulation results.

Fig. 4 represents total amount of energy consumed by all 31 nodes during 1 minute run of the protocols. Here we can easily say DGTT consumes 5, 12 and 3.5 times more energy than DSR, SGTT and HGTT respectively. Among the DGTT experiments, most energy-efficient choice is A3. This result is reasonable, because, from the previous experiments (Fig. 3) we found out that A3 is more effective than EECDS and CDS Rule K, moreover, ECDS and CDS-K were very close. Here the same.

In Fig. 5, total message traffic of the network is given. There is a huge difference between DGTT and the others. Actually, the number of sent messages is very similar, just HGTT is relatively higher. But, the number of received messages is very high in DGTT. It is 4 times higher than the runner-up HGTT. SGTT has the lowest total traffic in general. In fact, the reason of this big difference between the number of received and sent messages is broadcast style transmission and mass reception of
the broadcasted messages by all nodes in the range. This behavior artificially boosts the network traffic.

Probably the most important data is presented in Fig. 6: connectivity metric. It shows reliability and sustainability of the protocols via 2 different time intervals. Here, all DGTT combinations together get the highest value by %100 connectivity rate in both 1-minute and 5-minutes tests. Mobility (in the coverage area of course) does not cause impairment while using DGTT. Distinctly, if a node is in the communication range, then it will be included to the network via DGTT. The others have relatively lower values in 1-minute test and they become much worse by the time, as can be seen in 5-minutes test. In a 10-minutes test (which is not shown in the figure) ratios of SGTT and HGTT are below 25%.

![Connectivity levels during topology maintenance in 1 minute and 5 minutes of run](image)

Fig. 6 Connectivity levels during topology maintenance in 1 minute and 5 minutes of run

Manifestly, here, we discovered a clear tradeoff between energy spent plus message traffic and connectivity performance. There is no linearity, but the correlation is clear. Before evaluating the values given in Fig. 6, it wasn’t possible to say A3 or CDS-K or even EECDS can be a good choice. But after, we can say, for that type of a network, DGTT has the best results and preferable with A3, from the previous results.

So-called energy efficiency and traffic emptiness of SGTT and HGTT can be very deceptive. This is highly probable a paralogy, caused by the low connectivity and the link loss. Less links mean, less message receptions and less message receptions lead less energy consumption. Even so, this conjecture is valid for specific scenarios and could be different under variety of conditions.

All in all, although these values can give very valuable information and can provide guidance for related applications, the optimum decision is always application dependent. For instance, in a scenario that continuous communication is not as important as node lifetime (energy efficiency), DGTT should be avoided, while A3 could still be preserved.

We also evaluated the effect of BER on DGTT with A3, CDS-K and EECDS respectively. In Fig. 7, the relation between BER and connectivity is analyzed. It can be clearly seen that, a higher error rate lowers the connectivity metric significantly, but this relation is roughly logarithmical. While the error rate is $10^{-5}$, which is a de facto industry standard boundary, connectivity metric is very high; 97% to 100%. And until $10^{-3}$ values are acceptable. But one shouldn’t forget that, sensor data transfer is not included in this communication. It just represents topology control messagings. So, for higher level decisions about the architecture, level of the BER should be maintained no lower than $10^{-5}$ if the data sensed is time critical.

![Effect of the bit error rate on the connectivity ratio](image)

Fig. 7 Effect of the bit error rate on the connectivity ratio

![Effect of topology recreation time interval on connectivity and energy consumption based on 1 minute run using A3 + DGTT](image)

We discovered a clear correlation between connectivity and energy consumption, but this does not mean there is nothing to do to save energy. Figure 8 shows the effect of topology recreation interval during maintenance on both connectivity and energy consumption. First, please note that we used 500 ms movement sleep time and 1 s refreshing interval in previous experiments. Here we kept movement model as defined, but tested different time intervals. Hence, we exposed that, a refreshing frequency which is much higher than the movement speed (this also means physical deployment change frequency) causes extraordinary energy consumption and highly ineffective. We can also see that a frequency much lower, causes loss of communication links. Thus, a balance should be preserved to save energy and to protect connectivity at the same time. An interval 2 to 4 times longer than basic movement period looks acceptable in our case. As a final comment,
statistical information about the deployment environment and movement should be obtained to find a (sub-) optimal solution.

V. CONCLUSIONS & FUTURE WORKS

In this work, we aimed to show possible effects of the mobility to ad-hoc network performance and reliability in different aspects. Furthermore, we wanted to propose basic solutions.

In spite of the application dependability, we got some solid outcomes; first, unlike DGTT, SGTT and HGTT are not suitable for that type of a mobile network. One should better prefer a dynamic protocol, at least in a similar scenario like our presumption. Because of the connectivity level provided, we are not satisfied with the performance of static and hybrid methods. But in a different scenario, significant energy saving (we also found out that this is deceptive and caused by physical link loss) of these protocols can be exploited in a way.

Additionally, between the construction algorithms, A3 provides better values from the rest apart from Kneigh tree. But in long term, we showed that this advantage gained from construction phase becomes less significant by the time. Even so, A3 could be a reasonable choice for our scenario.

An impromptu (but predictable) observable (or solution) to the “connectivity-energy efficiency” problem is also given.

We got a strong impression about; building a cell-like structure by placing several stationary nodes in the deployment field could help us to reduce redundant traffic and to increase energy efficiency without downgrading the link quality. This hybrid network structure may give better results. This strategy should be researched and it can be a good extension to this work.

We still have no overall optimum choices, so search for a topology maintenance protocol that offers a better balance between energy consumption (or message traffic) and connectivity should go on.

Another point is super-speed mobility. We created a realistic human-like movement model; it can also be used for animals, or robotic structures. But super-speed mobility is not supported; in that case it is not even possible to construct a network. And even we deploy a cell structure, handovers would be a big problem. However, super-speed moving objects, including racing cars, satellites, missiles or so, rarely move randomly. They follow a track or orbit. This feature can be exploited. So, that aspect can also be another topic to investigate.

ACKNOWLEDGMENTS

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REFERENCES

Big Bang-Big Crunch Optimization Algorithm for Solving the Uncapacitated Facility Location Problem

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Abstract— The big bang–big crunch (BB–BC) algorithm has been proposed as a new optimization method based on the big bang and big crunch theory, one of the theories of the evolution of the universe. The BB-BC algorithm has been firstly presented to solve the optimization problems with continuous solutions space. If the solution space of the problem is binary-structural, the algorithm must be modified to solve this kind of the problems. Therefore, in this study, the BB-BC method, one of the population-based optimization algorithms, is modified to deal with binary optimization problems. The performance of the proposed methods is analyzed on uncapacitated facility location problems (UFLPs) which are one of the binary problems used in literature. The well-known small and medium twelve instances of UFLPs are used to analyze the performances and the effects of the control parameter of the BB-BC algorithm. The obtained results are comparatively presented. According to the experimental results, the binary version of the BB-BC method achieves successful results in solving UFLP in terms of solution quality.

Keywords— Big Bang-Big Crunch Algorithm, Population-based optimization algorithms, Binary optimization, UFLP, Modulo function

I. INTRODUCTION

Many swarm intelligence methods have been recently proposed in order to solve compelling optimization problems by reason of their simple structures and creation of influential solutions for problems [1]. Heuristics algorithms are the algorithms that employ a simple approach to produce an acceptable solution to search and are recently becoming powerful and getting more common. The reasons of that can be shortly given as follows:

In case of different decision variables, objective functions and constraints, they provide strategies of the general solution that can be practiced to the problem.

They independently operate from the type of solution space, the number of decision variables and constraints.

They utilize probabilistic random searches. They do not need excessive computation time because their computation power is in reasonable level.

The processes of their transformation and adaptation for different type of problems are simple.

They dictate fewer mathematical requirements and in addition, they do not need very well defined mathematical models.

They present impressive solutions for the large-scale combinatorial and non-linear problems.

They do not require the assumptions as done in standard algorithm.

They do not need the change on the given problem unlike the usual algorithms. They adapt themselves for solving different types of optimization problems [2].

In the last decades, different swarm-based evolutionary algorithms have been proposed for solving this optimization problem including Genetic Algorithms [3-6], Tabu Search algorithm [7, 8], Ant Colony Optimization [9], Particle Swarm Optimizer [10-12] and Artificial Bee Colony [13-15]. The random selection process and the information attained at the end of each iteration (cycle) are utilized in order to discover more optimal solutions in the subsequent iterations [16].

Big-Bang Big-Crunch (BB-BC) algorithm which is one of the swarm intelligence algorithms has been proposed by Erol and Eksin in 2006 for numerical optimization problems and was based on the big bang and big crunch theory, one of the theories of the evolution of the universe [17]. While in the Big Bang phase, the BB–BC method similarly produces haphazard points in solution space, in the Big Crunch phase it shrinks all of the points in the search space to a single agent point due to a centre of mass. It has shown that The BB–BC method outperformed the enhanced classical Genetic Algorithm on many benchmark problems.

According to the literature review, the basic BB-BC algorithm is a competitive algorithm in solving optimization problems with continuous solution space. If the solution space of the problem is binary-structured, the basic BB-BC algorithm must be modified in order to solve this type of optimization problems. Using modulo function that is one of the main mathematical operators, we propose a binary version of the BB-BC method for obtaining the reasonable solutions for binary optimization problems. The proposed method is investigated on a standard binary optimization problem by utilizing the uncapacitated facility location problem (UFLP). The UFLP is one of the most commonly used problems in combinatorial optimization. In this problem, the main objective is to minimize the total cost by providing the demand of customers under the given conditions that are a constant cost of setting up a facility and a shipping cost of satisfying the customer demand for the corresponding facility [10].
II. Basic Version of Big Bang Big Crunch Algorithm (BB-BC)

The BB-BC algorithm was firstly introduced for solving continuous optimization problems in 2006 by Erol and Eksin. This method is constructed on two main steps: the first phase is the Big Bang phase in which all of the candidate solutions are randomly distributed into the search space and the next phase is the Big Crunch where a center of mass is calculated considering individuals in the whole population [18, 19]. The initial population is randomly produced over the search space as done in the other swarm-based algorithms. All subsequent Big Bang phases are randomly distributed about the center of mass or the candidate with the best fitness value in a similar way. The most important feature of the algorithm is that it has high convergence speed but low computational complexity. For instance, while many evolution-based algorithms in the literature present near-optimal solutions at the end of too much iteration, BB-BC algorithm obtains solutions very close to the optimal solution of this problem on far less number of iterations in general.

After the Big Bang, a contraction procedure is implemented during the Big Crunch. In this stage, the contraction operator holds the available locations of each candidate solution in the population and its associated cost function value and calculates a center of mass. The center of mass is presented as follow:

\[ X^c = \frac{\sum_{i=1}^{N} \frac{1}{P_i} X_i}{\sum_{i=1}^{N} \frac{1}{P_i}} \]  

(1)

where \( X^c \) = position of the center of mass; \( X_i \) = position of candidate solution; \( P_i \) = value of cost function of candidate \( i \); and \( N \) = population size. The best fittest candidate solution can also be utilized as the starting point instead of the position of the center of mass.

After the second stage completes, new individuals are once again calculated for Big Bang stage according to the formula below.

\[ X_{\text{new}} = X^c + \frac{ir}{k} \]  

(2)

where \( X^c \), \( i \), \( r \) and \( k \) are respectively the centroid of mass, upper bounds of parameters, random parameter and number of iteration. The value \( X_{\text{new}} \) is calculated according to the following formula.

\[ X_{\text{new}} = \frac{\sum_{i=1}^{N} \frac{1}{P_i} X_i}{\sum_{i=1}^{N} \frac{1}{P_i}} + \frac{ir}{k} \]  

(3)

The steps of the BB-BC method are presented in Fig. 1.

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initialization Stage</strong></td>
</tr>
<tr>
<td>To initialize algorithm, the size of population, number of iteration, fitness function and error value are determined.</td>
</tr>
<tr>
<td><strong>Step 1:</strong></td>
</tr>
<tr>
<td>A population which consists of ( N ) individuals in search space is randomly generated.</td>
</tr>
<tr>
<td><strong>Step 2:</strong></td>
</tr>
<tr>
<td>The values of all the candidate solutions (individuals) are calculated by using fitness function.</td>
</tr>
<tr>
<td><strong>Step 3:</strong></td>
</tr>
<tr>
<td>The center of mass or the fittest individual is determined as Big Bang point by the help of Eq. (1).</td>
</tr>
<tr>
<td><strong>Step 4:</strong></td>
</tr>
<tr>
<td>A new population is generated about the center of mass or the best-fit individual.</td>
</tr>
<tr>
<td><strong>Step 5:</strong></td>
</tr>
<tr>
<td>Go to Step 2 until the stopping criterion (number of iteration or error value) is met.</td>
</tr>
</tbody>
</table>

III. Proposed Binary Version of BB-BC

Modulo base 2 is used to convert the continuous solutions to binary version. This conversion is presented in Eq.4.

\[ BS_{ij} = \text{mod}(|X_{ij} - \lfloor |X_{ij} | \rfloor)|, 2 \]  

(4)

where, \( BS_{ij} \) is binary solution obtained from \( X_{ij} \). \( \lfloor |X_{ij} | \rfloor \) is rounding operation to down, \( \text{abs} \) is a function used in order to obtain absolute value of \( X_{ij} \). When \( BS_{ij} \) is computed, first of all, rounding operator is applied to \( X_{ij} \), then absolute value of \( X_{ij} \) is obtained. As for last process, the modulo base two is applied to the obtained value.

\[ BS_{ij} = \text{round}(|X_{ij} - \lfloor |X_{ij} | \rfloor|) \mod 2 \]

An example of the solving Eq. (4) is presented as follows:

\[ BS_{ij} = \text{round}(|1 - 12.24|) \mod 2 \]

\[ BS_{ij} = \text{round}(12.24) \mod 2 \]

\[ BS_{ij} = 12 \mod 2 \]

\[ BS_{ij} = 0 \]

IV. Uncapacitated Facility Location Problem

In the basic formulation, UFLP consists of a set of customer location \( m \) that must be served, and a set of potential facilities \( n \) in which at least a facility must be opened and has not any capacity limitation. The main purpose (Eq. (5)) is to find a subset \( f \) of \( n \) facilities that is supplied request of customers \( m \). The objective function of the problem is to minimize sum of the transport costs. The mathematical formulation of the UFLP can be expressed as follows:

\[ f(UFLP) = \min\left(\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{i,j} + \sum_{j=1}^{n} f c_{j} y_{j}\right) \]  

(5)

subject to:

\[ \sum_{j=1}^{n} x_{i,j} = 1 \quad \forall i \in m \]  

(6)
where \( i = 1 \ldots m; j = 1, \ldots, n; x_{ij} \) represents the quantity supplied from facility \( i \) to customer \( j \); \( y_{j} \) expresses whether facility \( j \) is located \( (y_{j}=1) \); otherwise \( (y_{j}=0) \). The constraint in Eq. 6 ensures that demands of all customers must be satisfied by an open facility. The constraint in Eq. 7 provides the collectivity, as well.

The UFLP is one of the most crucial NP-hard problems in location theory [15, 20, 21]. In order to solve UFLPs, many exact methods, such as branch-and-bound [22], linear programming and Lagrangian relaxation [23], and dual approach [24], have been proposed. Despite the fact that these methods guarantee optimal solution, the computation time of these methods may be too much. For this reason, some approximate methods have been proposed in order to solve UFLPs. These methods cannot ensure the reaching of the optimal solution, but they can attain optimum or near-optimum solutions in a reasonable time.

V. EXPERIMENTAL RESULTS

The uncapacitated facility location test suite (12 test problems) obtained from the OR-Library was used in order to examine the performance and accuracy of the proposed binary versions of the BB-BC algorithm [25]. In the test suite, four problems (Cap71-Cap74) are small-sized, the four problems are medium-sized (Cap101-Cap104) the remaining four problems are large-sized problems (Cap131-Cap134) and the sizes and the costs of the optimal solutions for the problems are given in Table I.

<table>
<thead>
<tr>
<th>Problem name</th>
<th>Problem size</th>
<th>Cost of the optimal solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap71</td>
<td>16x50</td>
<td>932,615.75</td>
</tr>
<tr>
<td>Cap72</td>
<td>16x50</td>
<td>977,799.40</td>
</tr>
<tr>
<td>Cap73</td>
<td>16x50</td>
<td>1,010,641.45</td>
</tr>
<tr>
<td>Cap74</td>
<td>16x50</td>
<td>1,034,976.98</td>
</tr>
<tr>
<td>Cap101</td>
<td>25x50</td>
<td>796,648.44</td>
</tr>
<tr>
<td>Cap102</td>
<td>25x50</td>
<td>854,704.20</td>
</tr>
<tr>
<td>Cap103</td>
<td>25x50</td>
<td>893,782.11</td>
</tr>
<tr>
<td>Cap104</td>
<td>25x50</td>
<td>928,941.75</td>
</tr>
<tr>
<td>Cap131</td>
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</tr>
<tr>
<td>Cap132</td>
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</tr>
<tr>
<td>Cap133</td>
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<td>893,076.71</td>
</tr>
<tr>
<td>Cap134</td>
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<td>928,941.75</td>
</tr>
</tbody>
</table>

In order to make a clear and consistent comparison each other, the population size is taken as 40. For the entire experiments, the termination condition is selected as the maximum number of function evaluations (Max_FEs) and it is set as 80,000 and each experimental study performed by using center of mass and best fit individual instead of Eq. 1 and different upper limit \((\bar{l})\), which is one of the control parameter of the BB-BC, is run 30 times in order to solve UFLP. The mean, best and worst values and the standard deviations obtained by the runs are reported in Tables II-VII. The accuracy and robustness values of the methods are compared in terms of the mean and standard deviation, respectively.

In Table II, the experimental results obtained using center of mass function for value \(l=1\) is presented. The mean (Mean), standard deviation (Std), best value (Best) and worst values (Worst) obtained at the end of 30 times run are given for each problem. When analyzed the mean values, any success could not be gained under these parameters. However, when the best values are examined, the optimal results were obtained for small-sized and medium-sized problems problem groups but not large-sized problems. Besides, when looked at Table II and the other tables, it is seen that as the size of the problem increased, the average deviation from the optimal solution increased.

<table>
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<td>Cap134</td>
<td>50x50</td>
<td>928,941.75</td>
</tr>
</tbody>
</table>

The reporting results obtained using center of mass function for value \(l=2\) are given in Table III. When examined the mean values, it could not be reached to the optimal value for any problem under the given parameters. However, when the best values are examined, the optimal results could not be found for small and medium-sized problems problem groups except for large-sized problems. In addition, while the standard deviation values obtained from small-sized problems got lower, those of medium-sized and large-sized problem sets got higher. Therefore, it can be said that this method is more robust for small-sized problems than the other problem groups.
The experimental results attained utilizing center of mass function for value \( l = 3 \) are given in Table IV. When examined the mean values, the optimal value could not be found for any problem under the available parameters. However, when examined the obtained best values, it is seen that this method obtained optimal results for small-sized and medium-sized problems except for large-sized problems. In addition, while the standard deviation values obtained from small-sized problems got lower, those of large-sized problems got higher. Therefore, it can be said that this method is relatively more effective for small-sized problems rather than large-sized problems.

### Table III

**Experimental Results Obtained Using Center Function for \( l = 2 \)**

<table>
<thead>
<tr>
<th>Mean</th>
<th>Std</th>
<th>Best</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cap71</td>
<td>934166,882</td>
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<td>932615,750</td>
</tr>
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<td>979944,208</td>
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</tr>
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</tr>
<tr>
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<td>1040141,943</td>
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<tr>
<td>Cap710</td>
<td>804429,968</td>
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<td>796648,438</td>
</tr>
<tr>
<td>Cap102</td>
<td>863982,102</td>
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<td>854704,200</td>
</tr>
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<td>904765,695</td>
<td>8869,370</td>
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<td>Cap104</td>
<td>952661,198</td>
<td>17286,486</td>
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<td>Cap131</td>
<td>821229,431</td>
<td>18868,929</td>
<td>795883,238</td>
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<tr>
<td>Cap132</td>
<td>912322,125</td>
<td>21859,908</td>
<td>854704,200</td>
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<td>Cap133</td>
<td>980653,598</td>
<td>16274,168</td>
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<td>Cap134</td>
<td>1056551,117</td>
<td>25561,281</td>
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</table>

The final results obtained using best fit individual instead of center of mass function for value \( l = 1 \) are given in Table V. When investigated the mean values under these conditions, any optimal value for any problem could not be found. However, when analyzed the best values, it is seen that the proposed method reached to the optimal solution for small-sized and medium-sized problems problem groups but not large-sized problems. Besides, when analyzed the mean values in this table while this method obtained very near-optimal results for both of small-sized and medium-sized problems, it did not obtain good solution for large-sized problems. Therefore, it can be specified that this method is relatively more effective for small-sized and medium-large problem sets than large-sized problems.

### Table V

**Experimental Results Obtained Using Best Fit Individual for \( l = 1 \)**

<table>
<thead>
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<th>Mean</th>
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<th>Worst</th>
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<td>Cap72</td>
<td>978581,522</td>
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<td>1011318,064</td>
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<td>3883,140</td>
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</tr>
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<td>942813,938</td>
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</table>

The reporting results obtained utilizing best fit individual instead of center of mass function for value \( l = 1 \) are given in Table V. When investigated the mean values under these conditions, any optimal value for any problem could not be found. However, when analyzed the best values, it is seen that the proposed method reached to the optimal solution for small-sized and medium-sized problems problem groups but not large-sized problems. Besides, when analyzed the mean values in this table while this method obtained very near-optimal results for both of small-sized and medium-sized problems, it did not obtain good solution for large-sized problems. Therefore, it can be specified that this method is relatively more effective for small-sized and medium-large problem sets than large-sized problems.
The experimental results acquired utilizing best fit individual instead of center of mass function for value \( l = 3 \) are given in Table VII. When examined the mean values, this method could not reached to any optimal result for any problem. However, when looked at the best values, it is observed that this method reached to the optimal values for only small-sized and medium-sized problems problem groups. Besides, when analyzed the mean values while this method obtained very near-optimal results for small-sized and medium-sized problems problem groups, it did not acquire any good result for large-sized problems problem set. Therefore, it can be specified that this method is relatively more competitive for only small-sized and medium-sized problem sets.

### TABLE VI

<table>
<thead>
<tr>
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<th>Mean</th>
<th>Std</th>
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<th>Worst</th>
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<td>933520,538</td>
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### TABLE VII

<table>
<thead>
<tr>
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A. Comparative Analysis between Centre of Mass and Best Fit Individual

To fulfill a fair comparison, the experimental studies have been conducted under the equivalent parameters. In the process of comparison, Table II, III and IV are compared to Table V, VI and VII, respectively. In other words, to make a comparison between center of mass and best fit individual, the results of the corresponding problems have been compared under the same \( l \) values. As seen from Tables II - VII, when the proposed BB-BC\(_{\text{center}}\) method with Center of Mass is compared with BB-BC\(_{\text{best}}\) method with Best Fit Individual, BB-BC\(_{\text{best}}\) method is quite better in terms of both of solution quality and robustness rather than BB-BC\(_{\text{center}}\) method, in general. In addition, BB-BC\(_{\text{best}}\) method reached the very near-optimal solutions for the corresponding problems in all of the different \( l \) values. Based on the standard deviations, the robustness of the BB-BC\(_{\text{best}}\) method is better than that of the BB-BC\(_{\text{center}}\) method for all of the problems. When \( l \) values were set as one, two and three, the similar results were obtained. Therefore, for the entire problem groups (small-sized problems, 100s, 130s), it is observed that utilizing of different \( l \) values does not affect the success of the algorithm.

VI. CONCLUSIONS

In this paper, we studied the modification of the BB-BC method for solving binary optimization problems. Modula-2 based binary version of the BB-BC algorithm has been proposed and their performance has been investigated on uncapacitated facility location problems containing small and medium sized problem. The performance of the proposed methods is analyzed under the different \( l \) values which are upper value of the BB-BC method. In addition, the experimental results have been individually conducted using both of center of mass and best fit individual instead of center of mass and in view of these results, the comparative analysis between the BB-BC\(_{\text{center}}\) and BB-BC\(_{\text{best}}\) methods has been also carried out in this study. In experimental results, it is shown that promising results are obtained by this proposed binary method. The results show that the BB-BC method proposed for binary optimization can be used for solving other binary optimization problems.

REFERENCES


Image Mosaicing Based Condition Monitoring Approach for Multi Robots at Production Lines in Industrial Autonomy Systems

Hasan Yetis*, Mehmet Karakose*

*Department of Computer Engineering, Firat University
Elazig, Turkey
{h.yetis, mkarakose}@firat.edu.tr

Abstract—In today industry, manufacturing become big and serial as it never been before thanks to the autonomy robots. Hitches on such autonomy systems used in industrial production may cause production delaying. In this study, it is aimed to obtain alive bird's eye view map of full system in order to monitor manufacturing robots at production facilities that are big and impossible to be monitored with only one camera. Finding the similar scenes of input images, estimation of homography, warping and blending operations are applied respectively in order to mosaic the images by twos. Thus the robots in the facility can be observed in one screen. With observation of the obtained images, faults on cyber-physical systems that may cause damage in machines which are not cheap can be handled beforehand.

Keywords—Condition monitoring, Multi robots, Production lines, Image processing, Image mosaicing

I. INTRODUCTION

Accuracy and security of cyber-physical systems become crucial with growing up cyber-physical systems in industry. In today industry, manufacturing become big and serial as it never been before thanks to the autonomy robots whose cyber and physical layers are diverse. Monitoring physical layer from cyber layer is necessary for link the layers and integrate them more tightly. Furthermore, it will ease the control of big facilities. Hitches on cyber-physical systems used in industrial production may cause production delaying. Furthermore, these hitches may cause damage in hardware which are not cheap. So observation of the system and determination of possible accident are required for deduction the cost of delay in production and repair. With processing the obtained image by algorithms in cyber layer, the cyber-physical system would be more integrated and secure.

In this study, it is aimed to obtain alive bird's eye view map of full system in order to monitor manufacturing robots at production facilities that are big and impossible to be monitored with only one camera. With the created alive map, it will be possible to monitor positions of all robots instant and extract more detailed information about the facility. It is need that locate cameras each of whose angel of vision contain the small piece of neighbour one's. Finding the similar scenes of input images, estimation of homography, warping and blending operations will be applied respectively in order to mosaic the images by twos. After all steps done, only one stitched image will be obtained from all these images taken by cameras at the same time. Thus the robots in the facility can be observed in one screen and machines which could lead to accidents can be noticed early. The stitched image can also be used for image processing in cyber layer.

There are studies about image mosaicing in literature [1-5]. One of the studies, Divya et al. [1], implemented weighted average method in addition to the methods used in image mosaicing such as feature extraction, cluster analysing, dynamic programming to obtain wide angle panorama. Although the study is effective for illuminated images, it is not useful for dark images. Another study about this subject is Lin’s study [2]. Lin et al. use image mosaicing in order to obtain cylindrical panoramic image. Scale Invariant Feature Transform (SIFT) and Random Sample Consensus (RANSAC) are used in this study. Patel et al. [3] employ Speeded-Up Robust Features (SURF) for feature extraction and Sum of Squared Differences (SSD) for feature matching. They also used RANSAC to eliminate incorrect matchings. At the end of their study, they compare Harris and SURF and decide that SURF is more effective for multi-imaged image mosaicing problems. Huang et al. effort to mosaic frames in videos [4]. Instead of using all frames in a video, they used the frames that contain small piece of other frame to enhance video mosaicing performance. In their study, Lee et al. [5] employ SURF for feature extraction and Histogram of Gradient (HoG) for matching. They also utilize from Approximate Nearest Neighbour (ANN), RANSAC algorithms.

![General Image Mosaicing Steps in Literature](image.png)

Figure 1. General Image Mosaicing Steps in Literature [6]
Qui et al. aimed to stitch images and eliminate ghosts occurred while stitching images [7]. In this manner they used SIFT and RANSAC methods. In order to obtain optimal stitching line dynamic programming methods are employed. Larqui et al. [8] also employ SIFT for feature extraction. Difference of their study is that they use voronoi diagram to eliminate incorrect matches.

The paper continues with information about image mosaicing that is given in section 2. In section 3 simulation results are given. Conclusion is handled in section 4 and references are listed following conclusion.

II. IMAGE MOSAICING

Image mosaicing is the process of obtaining single image from more than one images that contain common view with corresponding of the matching points. It helps to obtain qualified images with not expensive cameras [9], take the image of scenes that can not be viewed with one camera, obtain panoramic images, delete moving objects in a video. It has a wide application area from smart systems to military systems.

Regardless the count of images that will be stitched, the images are stitched by twos as seen in figure 2. There are stitching methods in space and frequency domains. The methods in space domain can be grouped as area-based methods and feature-based methods [10]. In this paper, feature-based techniques are applied because area-based techniques are sensible for changes in size, angle and illumination. In feature-based image mosaicing methods, interest points that are characteristic points in image and their features are found first. With the help of extracted features, matching operation is applied. Mismatches that may be occurred are eliminated and homography is estimated. With the found homography matrices warping operation is actualized and blending is applied to make the stitching seamless [11]. General steps of feature-based image mosaicing process are given by Fig. 3.

A. Feature Extraction

In order to stitch images, it is required to determine common areas / objects first. Feature based methods use characteristic points called interest point instead of all pixels in an image in order to make algorithm more efficient. Interest points can be edges, corners or blobs. There are several edge and corner detection methods to identify the interest points [13,14]. In this paper, interest points are extracted by Difference of Gaussian (DoG) method which is a blob detection method.

In order to link between images, interest points are used. Some features must be extracted for calculating the similarity of interest points. There are various feature extraction methods in literature [15]. In this study, we used Scale Invariant Feature Transform method [16].

B. Matching

After extracted SIFT features, it is searched corresponding interest points from second image to interest points from first image according to similarity [17]. In this stage second nearest neighbour distance rate is used to prevent mismatches [18]. According to this method the distance between interest points from reference and target image are calculated. The nearest 2 corresponding interest points are selected for each interest point from reference image. If the first distance is smaller than the multiply of distance ratio and second distance, it means there is no confusion probably and the first one selected as matched point. Otherwise it means there is confusion and no matching is realized.

$$\text{matching} = \begin{cases} 1, & A < B \times \alpha \\ 0, & \text{otherwise} \end{cases}$$

where A is distance of first nearest point, B is distance of second nearest point and \(\alpha\) is tolerance of distance difference.
C. Elimination of Mismatches

Although the second nearest neighbour distance method reduce the count of mismatches, it can not completely eliminate them. When we try to superpose the matched interest points, the mismatches make a fuss. So, the count of mismatches must be minimized before homography estimation. In this study RANSAC is used to eliminate the mismatches.

According to RANSAC method [19], some of the data are selected randomly and a model is tried to fit the samples. After all data are tested by the model respectively. If the model gives the correct result within the tolerance defined before, the datum is marked as in-liner. If in-liner data is sufficient to verify the model, the model is added to solution set. This operation is actualized pre-determined iteration times. At the end of the iterations best model that fits the majority of data with minimum error is selected as solution. The diagram belongs to RANSAC algorithm is given by Fig. 4.

D. Homography, Warping and Blending

We aimed to fit a model whose input is the pixel coordinate of target interest points and output is the pixel coordinate of corresponding reference interest point. The model that help us to calculate the new position of target image pixels’ in order to superpose these images is called homography matrices. Homography matrices is 3x3 sized matrices and it is used to move the points in homogeneous coordinate system. The equation for calculating new position of point and and its extended version are given by respectively (1) and (2).

\[ \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} = \begin{bmatrix} X_n \\ Y_n \\ Z_n \end{bmatrix} \]

(1)

\[ \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} X_o \\ Y_o \\ Z_o \end{bmatrix} = \begin{bmatrix} X_n \\ Y_n \\ Z_n \end{bmatrix} \]

(2)

where H is homography matrices, P and P’ are former and new coordinates of pixel in homogenous coordinate system respectively. To transform 2 sized vector to homogenous coordinate system, \( Z_o \) is selected as 1; to transform homogenous coordinate system to X and Y values (3) is used.

\[ X' = \frac{X_n}{Z_n}, \quad Y' = \frac{Y_n}{Z_n} \]

(3)

where \( X' \) is new value of X and \( Y' \) is new value of Y. After found of new coordinates of target image, target image is transformed and coordinates of corresponding points be the same. With the displaying transformed image and reference image in one frame, image stitching process is done.

Stitched image may have visible colour transition because of the cameras whose angel of vision is not illuminated as same as the other one’s. At last, to extinguish the difference blending operations are used [20]. In order to remove blur that may be derived from stitching operation or derived due to the high speed of robots at production line, some blur removal methods in literature can be used [21].

III. EXPERIMENTAL RESULTS

In this paper, the image stitching operation is implemented on images that belongs to robots at production line. The diagram of desired system given by Fig. 5. Although the sample system shown by Fig. 5 includes 4 cameras with the same characteristics, the count of cameras can be increased. A computer with intel i7 6020M CPU, 6 GB ram, and Windows 7 64bit home premium is used to perform the proposed approach on the sample images belong to production environment.

Figure 4. Block Diagram of RANSAC Algorithm [22]

Figure 5. Desired system for grabbing images.
In order to test the effect of the images order, the four image given by Fig. 6 are stitched respectively first. The result of this process is given by Fig. 7. Then the same images are subjected to the process of stitching by twos. In Fig. 8, e is obtained by stitching of a and b, f is obtained by stitching of c and d, and finally g is obtained by stitching of e and f.

Although there is not much difference in point of the quality between final stitched images that are obtained in Fig. 7 and Fig. 8, we can see that the process given in Fig. 8 works faster than the process given in Fig. 7 when we look elapsed time given in table 2 and table 3.

<table>
<thead>
<tr>
<th>Searching Area</th>
<th>Search Size</th>
<th>Found IP</th>
<th>Matched IP</th>
<th>Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full of a</td>
<td>336 x 189</td>
<td>681</td>
<td>84*</td>
<td>29</td>
</tr>
<tr>
<td>1/3 of a</td>
<td>111 x 189</td>
<td>205</td>
<td>87</td>
<td>13</td>
</tr>
<tr>
<td>1/5 of a</td>
<td>66 x 189</td>
<td>123</td>
<td>47</td>
<td>7</td>
</tr>
</tbody>
</table>
TABLE II. THE PERFORMANCES OF STITCHING BY ORDER WITH FULL SEARCH AREA

<table>
<thead>
<tr>
<th>Process in</th>
<th>Size</th>
<th>Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>560 x 189</td>
<td>65</td>
</tr>
<tr>
<td>f</td>
<td>560 x 310</td>
<td>92</td>
</tr>
<tr>
<td>g</td>
<td>560 x 310</td>
<td>123</td>
</tr>
<tr>
<td>Total</td>
<td>560 x 310</td>
<td>280</td>
</tr>
</tbody>
</table>

TABLE III. THE PERFORMANCES OF STITCHING BY TWO'S WITH LIMITED SEARCH AREA

<table>
<thead>
<tr>
<th>Process in</th>
<th>Size</th>
<th>Time (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h</td>
<td>560 x 189</td>
<td>15</td>
</tr>
<tr>
<td>i</td>
<td>560 x 189</td>
<td>16</td>
</tr>
<tr>
<td>j</td>
<td>560 x 310</td>
<td>28</td>
</tr>
<tr>
<td>Total</td>
<td>560 x 310</td>
<td>59</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

It is very crucial to monitor physical elements especially for cyber-physical systems that is trend of the industry of today, which is called industry 4.0. In this paper, it is proposed that use image mosaicing to monitor conditions of multi robots at production lines and the proposed method is tested by experimental. In order to test the method 4 images that belongs the same science are used, and no one of them contains more than 1/3 of another one in spite of the possible deflections. With the knowledge of this, only a part of image is used to search interest points instead of full image. Finding interest points, feature point extraction, matching, warping and blending operations are used respectively to stitch images. Since the order of images that are stitched are certain, sorting of images is not required for such camera array applications. The images are stitched by order and by twos respectively. The effect of image order is demonstrated by results given by table 2 and table 3. The results show that stitching by twos outperforms stitching by order for the camera arrays which occurred from NxN camera, N is even number. Furthermore, if N is not even or the size of camera array is not NxN, a sub array that provides the constraints and the operation is applied for sub array. After the remains may be stitched by orders. Little time consumption of this approach make it possible to be used in camera array problems. The feature-based method makes the solution more reliable in case of changing in position, angle or illumination.

Consequently, it is possible to get high quality reliable image using low quality cameras thanks to the method. Monitoring the condition of robots at production line, which is a requirement for today’s industry facilities, in a screen is achieved by the study.

REFERENCES

Defining Crowd Movement as Parabola and Classifying These Definitions

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Abstract—Smart surveillance systems developed in recent years have made enormous contributions to providing safety and management of crowds. The aim of this study is to observe and try to understand how crowd movements presented in a video sequence show behaviour. For this end, the motion data at pixel level among the consecutive frames is obtained using optical flow initially. Then, this motion data is associated using the particle advection method and stable as well as moving areas in the image are obtained. After, the moving areas clustered using Mean-Shift method are described and classified as parabola, in addition to the studies in the literature. At the end of the study, the method developed was tested over UCF as well as Pets2009 datasets and the results are presented.

Keywords Crowd Analysis, Particle Advection, Optical Flow

I. INTRODUCTION

The flow of the daily life, willingly or unwillingly, integrate people in crowds. Streets, shopping malls, political meetings, stadiums or concerts are centres where crowds are abundant. It is possible for a crowd in calm movement to become a crowd of people running in panic all of a sudden. Although this case would not last long, but it may cause stampede and may result in losses of lives. It is quite easy for a person with suspicious behaviour to disguise himself in the crowd. These are bad incidents that have a higher percentage of lethal possibility and realization. Humanity has already experienced such bad incidents. Such sorrowful incidents experienced have shown the need for making studies on the analysis of crowd behaviour. Different disciplines such as computer vision, sociology, and psychology have been doing research on this topic for many years.

In this respect, researches such as estimating the density of the crowd and observing the flow by developing algorithms on images obtained from surveillance systems; noticing the generation of a dangerous crowd or predetermining the abnormal conditions in the crowd; managing the crowd in panic; designing the open public spaces; and tracking a suspicious person or people throughout a series of images; have been the primary topics of crowd behaviour analysis studies. Some images where there are crowd scenes are shown in Figure 1.

Crowd analysis problems were tried to be solved by algorithms developed for object tracking in the first years (Object approach) but it was seen that tracking people in high density videos is fairly difficult and that this is a solution that needs burdensome and excessive calculations. In the following studies, it was tried to grasp the general features of the crowd rather than focusing on the people in the crowd as a whole (Holistic approach).

Through the survey based publications in recent years, the topic has been handled with different issues such as determination of moving areas, crowd analysis, crowd behaviour, tracking of people, and determination of abnormal conditions. Methods that are used under these topics and success results obtained from these are being compared and evaluated. Moreover, there are studies from the perspective of different disciplines. [1][2][3][4][5][6][7]

Segmentation of moving areas in crowd provides a general view of the image. By focusing on these moving areas, this process plays an important role in the solution of problems such as determining the abnormal conditions or tracking of people. Insufficient or erroneous results in the segmentation process have a negative effect on the preceding steps. Because of this condition, studies on determining the moving areas go on developing every day. [8][9][10]

Incidents, not occurring frequently except for the general flow of a crowd, are called Abnormal Behaviour in the literature. Another important study in which a solution is looked for through computer vision methods is the determination...
of abnormal condition or behaviour in crowd by systems. Using such systems in high density areas such as shopping malls, stadiums, concerts or passenger stations presents an alternative approach to providing the safety and management of crowds. [11][12]

Another important issue on the crowd analysis field is the tracking of a person or people in a crowd. It is a very difficult thing to keep a track of people in high density crowds. The main reasons are; I) the denser it gets, the less pixel representing the person there will be, and this makes tracking more difficult. II) It is difficult to differentiate people in crowds. III) There are psychological conditions having an influence on the change of people’s direction.

Problems such as tracking of a person or moving objects (vehicles in traffic) after being determined in the image during a series of images are specialized fields where academic studies deal with in private and create private algorithms (tracking algorithms). In such studies, problems are tried to be solved by an object based approach.[13][14]

Estimation of density of a crowd is an important topic in terms of providing the safety and management of the crowd. It is crucial to make these analyses and these controls dynamically at places where there are crowds and crowds show variability, such as stadiums, concerts, and shopping malls. By this way, it will be possible to prevent potential condensations. These analyses are performed on a single image. Conditions such as few pixels per person, the perspective, cluttering, occlusion, and low resolution are important problems that these analyses should find a solution for.

Our target in this study is to obtain the moving areas in an image using optical flow method and defining the moving areas as a parabola. Moving areas that are defined as equation will give us information about how the crowd behaves. We believe that the results that are obtained from these studies will help us understand and define the behaviour of the crowd in the preceding steps. At the end of the study, the developed method was presented as ground truth by being tested on the images from UCF and Pets2009 database.

II. METHODS

Some methods that were used in order to obtain some characteristics of the crowd and to observe how the crowd moves clearly will be explained in a priority order.

A. Optical Flow

This is a method used in order to obtain movement data in a video. In this method, the direction and the speed of object movements in consequent frames at pixel level can be obtained. This method is usually used for obtaining the movement data at lower speeds and at high density. It is seen that the method proves to return better results in videos with these qualifications.[15][16][17][18]

When we take the prerequisite that the light source does not change in time and that the change is not more than 1 pixel (in relocations more than 1 pixel, the pyramid method is recommended but this is not included in this article) into consideration, we can have this equation, provided that the pixel at (x,y) location in t time can relocate as much as (dx,dy) in t+1 time period.

$$\frac{dI}{dt} = 1 \Rightarrow I(x,y,t) = I(x + dx, y + dy, t + dt) \quad (1)$$

When the process is proceeded using Taylor series;

$$I(x, y, t) = I(x, y, t) + \frac{\delta I}{\delta x} dx + \frac{\delta I}{\delta y} dy + \frac{\delta I}{\delta t} dt + H.O.T \quad (2)$$

$$Ixu + Iyv = -It \quad (3)$$

The general formula of the optical flow is obtained. ($Ix = \delta I/\delta x, Iy = \delta I/\delta y, It = \delta I/\delta t, u = dx/dt, v = dy/dt$).

In equation (3) that is obtained as the movement data of a single pixel, there are known values such as $Ix, Iy, It$ and also known values but also unknown values such as $u$ and $v$ values. The aim of the optical flow is to find the $u$ and $v$ values.

At this level, a solution was developed benefiting from the method developed by Lucas-Kanade for optical flow. Lucas-Kanade calculated the velocity of a pixel taking into consideration of the fact that a pixel moves at the same velocity with neighbouring pixels. That is to say, when calculating the movement of a pixel that has a 3x3 neighbouring scheme, we obtain 9 equations in order to find the two unknowns of $u$ and $v$ in equation (3), thinking that all the neighbouring pixels move at the same velocity.

$$\begin{bmatrix} Ix_1 & Iy_1 \\ Ix_2 & Iy_2 \\ \vdots & \vdots \\ Ix_9 & Iy_9 \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} -It_1 \\ -It_2 \\ \vdots \\ -It_9 \end{bmatrix} \quad (4)$$

The neighbouring window chosen as 3x3 in the sample can be chosen at different sizes depending on the condition of the problem.

While preferring a smaller size of window value can help us obtain the details in an image, these details might lead to image confusion and the load of the system might increase. Moreover, it may also lead to the loss of general flow data of the video. On the other hand, a larger sized neighbouring window can capture the movements at larger scale and helps us obtain the general flow of the movement,
yet the bottlenecks or small movements might not be noticed. There is a trade off in question. Therefore, the size of the neighbouring window is another problem to think about.

When the equation (4) is solved using minimum least squares method:

$$A^T A \mathbf{d} = A^T \mathbf{b}$$

$$2 \times 2 \quad 2 \times 1 \quad 2 \times 1$$

$$\begin{pmatrix} \Sigma I_x I_x & \Sigma I_x I_y \\ \Sigma I_x I_y & \Sigma I_y I_y \end{pmatrix} \begin{pmatrix} u \\ v \end{pmatrix} = \begin{pmatrix} \Sigma I_x I_t \\ \Sigma I_y I_t \end{pmatrix}$$

(5)

There are four basic steps to be taken in obtaining optical flow using Lucas-Kanade method.
- Noise reduction is applied in frames
- Ix, Iy, and It are calculated
- u and v values are found by calculating the equation (5).
- Due to the fact that optical flow values are independent from each other and that they might show differences from the general flow, the resulting values (u,v) are applied a median filter.

B. Particle Advection

Optical flow provides the data related to where a pixel will be heading to on the next frame. Particle Advection, on the other hand, is a method used in order to observe (understand) how a pixel moves throughout the video.[19][20][21]

At this level, particles that are located on every pixel in the first frame of the video are being directed by the time domain pixel level 3D movement data that is obtained by optical flow. At the end of the process, the time domain 3D optical flow data is obtained as 2D movement data. This process is called particle advection and the distance covered by each particle is called particle trajectories. [22][23][24][25][26][27]

A grid is located on 1th frame in video sequence, namely each pixel in the first frame and the particles are moved according to optical flow data. Ideally, a grid is made up as N=Width X Height. Particle advection can be formulized according to notation expressed above.

$$x_i(t+1) = x_i(t) + u(x_i(t), y_i(t))$$  (6)

$$y_i(t+1) = y_i(t) + v(x_i(t), y_i(t))$$  (7)

C. Clustering

Differentiating multiple actions on an image from each other successfully is directly related to the success of the cluster process. The particles animated with the help of Particle advection process in fact carry the motion data and at the end of the process particles representing any action gathers at a cluster point. It is expected from the system to differentiate these clusters from each other. We can think that each cluster represents an action. In this study, we tried to obtain clusters using mean-shift method.[28][29]

Some places on the image might not move and therefore the particles on these pixels do not move. In this case, particles not moving or moving at a value lower than the threshold value and clusters emerged under a definite number of particles are accepted as noise and they are not included in the evaluation. By this way, only clusters that have the capability to represent motion or define a significant motion can be obtained.

D. Define as Parabola

In this step, the moving areas in the image will be defined as parabola. In this way, these results will be helpful in terms of determining moving areas and understanding the crowd behaviour.

Determining as moving parabola can be as follows; particles representing an action or behaviour move as a group with particle advection. This information can be expressed as a curve using least squares method according to the location of each particle has along the motion.

$$f(x) = ax^2 + bx + c$$  (8)

$$a = \begin{cases} 
\text{line} & \text{if } a \approx 0 \\
\text{circle} & \text{others}
\end{cases}$$
For this study, when we express each movement as a quadratic equation, it can be said that proximity to coefficient \( a \) (8th equation) shows whether this movement is a line or circular movement.

III. CONCLUSION

As a result, this study is a preliminary study that can make it possible to achieve targets like understanding and defining the behaviour of a crowd during a series of images. Initially, moving areas are obtained through optical flow method and then these moving areas are defined as the movement of particles through particle advection method. Particles clustering at a point on the image are marked with mean-shift method and behaviour at different types are determined. The movement is represented through a quadratic equation according to the location of particles in each cluster. In the end, it is possible to achieve the information on what kind of route the co-efficient of these equations follows.

The methods were tested on some images that we took from UCF and Pets2009 database. The results were shown as ground truth in Figure 3.

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Vibration Analysis for Induction Motors with an Expert System

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Abstract—This paper presents an expert system for induction motor fault detection based on vibration analysis by using corvid expert system. Vibration signals of induction motors on four different actuating mechanism are collected with a specific vibration measuring device. The device evaluates the values with three harmonics in frequency domain. Expert system provides the recommendations as maintenance activity or the reason of the vibration by using vibration values. This system is tested and validated on four type of actuating mechanisms. Obtained results show that this system can detect faults in early stages with high accuracy and reliability. Thus, it provides malfunction and failure prevention and improves overall performance and efficiency of industrial systems.

Keywords—fault detection, induction motor, vibration analysis, data analyse, expert systems.

I. INTRODUCTION

Induction motors play an important role as prime movers in manufacturing, process industry and transportation due to their reliability and simplicity in construction. Although induction motors are reliable, the possibility of unexpected faults. The issue of robustness and reliability is very important to guarantee the effective operational condition. Therefore, condition monitoring of induction motors has received considerable attention in recent years. Early fault diagnosis and condition monitoring can reduce the consequential damage with unexpected production stops. Faults can occur in the stator, rotor, bearing, or the external systems connected to the induction motor. Because of this reason, fault diagnosis of engineering plant has increased recently.

Expert Systems contain specialized knowledge elicited from a domain expert usually in the form of IF-THEN rules. Expert systems are widely used in fault detection and diagnosis applications [1]. The knowledge engineer usually extracts rules for the given domain, in this case, fault diagnosis system for induction motors, and the inputs of expert system are the measurements taken by sensitive instruments, i.e. sensors. The expert system then proceeds on to reasoning with rules and infer meaningful recommendations. The present research is based on using motor vibration data measured with a professional device and use these results obtained from the device for diagnosing faults in an induction motor.

II. VIBRATION ANALYSIS

Vibration is the cyclic or oscillating motion of a machine or machine component from its position of rest. Vibration is a repeated action and is continuous. Most vibrations are undesirable in machines and structures because they produce increased stresses, energy losses, cause added wear, increase bearing loads, induce fatigue, create passenger discomfort in vehicles, and absorb energy from the system.

The amplitude of the vibration can be measured as displacement, acceleration or velocity. Displacement is a distance for moved object. Its measurement unit is mm (millimeter). Acceleration is a difference the rate of the velocity and is measured as mm/s².

The amplitude of the vibration can be measured as displacement, acceleration or velocity. Displacement is a distance for moved object. Its measurement unit is mm (millimeter). Acceleration is a difference the rate of the velocity and is measured as mm/s².

Displacement accentuates the low frequencies. Acceleration accentuates the higher frequencies. Velocity is consistent across a larger range of frequencies as presented Figure 1.

Vibration data can be collected through the vibration sensors. Vibration sensors can be classified as accelerometers, velocity sensors, capacitive and eddy current sensors and laser displacement sensors. All these sensors have some advantages and disadvantages according to the application. After the values are collected vibration analysis should take place. Vibration analysis consist of some logical steps. These are detection, analysis and correction. Detection should be implemented by the devices or sensors then analysis occurs by software program or just like ours with an expert system. The last step is the correction through the analysis. A systematic vibration analysis can then be carried out to identify the more common machinery problems, including: Unbalance, Misalignment, Looseness, Defective Bearings, Resonance, Eccentricity, Worn Gears, Motor Electrical Problems, Drive Belt Problems,

Figure 1: Amplitude – Frequency Chart
Distortion (Soft-Foot & Piping Strain). Diagnostic Charts are implemented to make rules for expert system.

![Unbalance Diagnostic Chart for Fan Mechanism](image)

**Fig. 1**: Unbalance Diagnostic Chart for Fan Mechanism

Mass unbalance will be in phase and steady as shown in Figure 2. Amplitude due to unbalance will increase by the square of the speed below first rotor critical (a 3X speed increase = 9X higher vibration). 1X RPM always present and normally dominates spectrum.

### III. EXPERT SYSTEM DESIGN AND IMPLEMENTATION

Expert systems are computer programs that emulate the interaction that a person would have asking a human expert for advice or a recommendation. Most decision-making processes can be broken down into many small parts. The human expert often makes decisions almost automatically and does not consciously think about each small step to solve problems or reach conclusions. However, they become apparent when the reason for the decision is explained to someone else, or the decision process is taught to others. A decision may be based on various facts that individually would not be conclusive, but when combined together lead to a specific decision or diagnosis.

The kernel of an expert system has two main components. Namely the knowledge base and the inference engine. The knowledge base contains knowledge about the expert’s domain. It may be represented by simple facts, or by more complex representations like frames. There are also rules which explicitly represent the expert’s skills or knowledge about the domain under consideration. The expert system uses this knowledge by exploiting the second main component, that is the inference engine which has several roles including determining how the system reasons using the IF-THEN rules in the knowledge base. Once the knowledge base is built, the ES can begin making inferences. The most common forms of inferencing are forward and backward chaining. The process of moving forwards from known facts to conclusions that follow them is called forward chaining. Alternatively, the process of working backwards from an hypothesis to known facts that support it, is called backward chaining.

Various expert system building tools or shells exist to facilitate and speed up the development process. In the present study, the new generation Exsys Corvid tool has been utilized [3]. Exsys tools have traditionally been used a pure rule-based approach to logic and this has proven to be extremely effective with heuristic rules [2]. There are many ways of describing the heuristics for a decision-making process, but the one that has proven the most effective and efficient is the IF/THEN rule. This is a rule where there is an IF part that can be tested to be true or false based on the data for a specific case or situation.

When the IF part is true, the statements in the THEN part are also considered true.

A sample dialog for Motor – Belt – Fan Mechanism is as follows:

**IF**: Choose the actuating mechanism: Motor – Belt – Fan

**AND**: Choose measuring point: Horizontal Vibration

**AND**: Is there any pick vibration value before the [Vibration Value1X], Evet

**AND**: [Vibration Value2X] = 0

**AND**: Vibration value3X] = 0

**THEN**: ‘‘There is a misalignment at the center of motor side. Maintenance is necessary. ‘’

### IV. EXPERIMENTS AND RESULTS

Expert system for induction motor fault detection presented in this paper implements all previously stated phases of the detection process. The measurements have been taken on the Motor- Belt – Fan mechanism by vibration device as presented in Figure 3. There is a peak value on the first harmonic as shown in Figure 4 that means there is a misalignment on motor side as recommended at expert system forward chaining rule structure. The system has recommended to the maintenance team before the problem has occurred that means the system has prevented the production loss and has guaranteed production stability.

![Motor – Belt – Fan Mechanism](image)

**Figure 3**: Motor – Belt – Fan Mechanism

![Vibration Value of Motor – Belt – Fan Mechanism](image)

**Figure 4**: Vibration Value of Motor – Belt – Fan Mechanism
V. CONCLUSION

In this paper an expert system for induction motor fault detection is presented. Using programming software tool Exsys Corvid System and packages combined with appropriate hardware and implementing forward chaining rules, this system is intended to be used as a practical diagnostic tool for condition monitoring and fault, malfunction and failure prevention in industrial systems. The system is tested in real industrial environment and obtained results proved its accuracy and efficiency.

Further research could be conducted in several directions with new type of vibration sensors. First of which would be to extend the number of faults covered by the classification, such as unbalance, misalignment, looseness, defective bearings, resonance, eccentricity, worn gears, motor electrical problems, drive belt problems, distortion (Soft-Foot & Piping Strain) at four different actuating mechanism. This would enable more efficient fault detection based on more comprehensive feature sets, which would improve maintenance procedure and decrease total cost in production processes.

REFERENCES

Security Evaluation of IOS and Android

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Abstract— In the race of smartphone operation systems, IOS and Android seem to have the big part of pie. Both platforms have grown more enterprise-friendly since about one decade. Their adaptable functionalities make people's lives easy and give them a reputation in the current competitive technology world. We all have our personal thoughts it comes to features, usability and design. However, what about security? Mobile devices, smartphone operation systems run on, hold valuable, sensitive and classified information or content. So, that increases their attractiveness as targets for cybercriminals. The security of these devices is a growing concern and focus point for smartphone users. Eventually, the security technology of the smartphones becomes one of the prime research and these smartphone vendors have increasingly focused on security in their design efforts. In this paper, factors that influence security within IOS and Android are studied to promote the discussion. Security technologies of IOS and Android are briefly presented. And, varies factors are considered such as methods of application distribution, reduced attach surface, privilege separation, permission-based access control, sandboxing, data encryption, data execution prevention and address space layout randomisation, geo-location and auto-erase. Then, brief information is given about malicious apps. Lastly, discussion is concluded to answer that tight question in the light of security models investigation and evidences collected from current life.

Keywords— mobile security, mobile device, mobile OS, IOS, Android

I. INTRODUCTION

Mobile devices are rapidly becoming the platform of choice for consumers and businesses. There is a wide range of functionalities provided to the users by the mobile devices such as fast connection to social platforms, personal data storing, financial processes, web browsing and tons of services. Therefore, the smartphones sales achieve high number of records worldwide and going on to suppress other electronic technologies like notebooks and tablets [1]. On the other hand, while the number of mobile devices increased, the security threats such as privacy violations, malicious code and exploits in smart environment increased. According to a recent report from Gartner, global smartphone sales are estimated to reach 1.5 billion units in 2016, a 7 per cent growth from 2015 [2]. Also, worldwide smartphone sales to end-users by operating system in 2014 and 2013 are shown in Table I [3].

<table>
<thead>
<tr>
<th></th>
<th>2014 (Units)</th>
<th>2013 (Units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Android</td>
<td>1,004,675</td>
<td>761,288</td>
</tr>
<tr>
<td>IOS</td>
<td>191,426</td>
<td>150,786</td>
</tr>
<tr>
<td>Windows</td>
<td>35,133</td>
<td>30,714</td>
</tr>
<tr>
<td>BlackBerry</td>
<td>7,911</td>
<td>18,606</td>
</tr>
<tr>
<td>Other OS</td>
<td>5,745</td>
<td>8,327</td>
</tr>
<tr>
<td>Total</td>
<td>1,244,890</td>
<td>969,721</td>
</tr>
</tbody>
</table>

As mobile platforms become increasingly popular, so do the incentives for attackers, especially when mobile payment transactions are projected to reach almost US$630 billion by 2014. Recent security surveys describe the rapidly increasing number and sophistication of mobile attacks. Mobile devices' prevalence and mobile threats' rapid growth have resulted in a shortage of mobile-security personnel [4].

The storing of sensitive personal data in the smartphones and the increasing popularity of smartphones, lead them to attract the hackers' attention [5]. Cybercriminals have found many sophisticated ways to perform malicious activities on mobile devices. Cybercrimes such as identity theft, information theft, distribution of malwares, and financial fraud have become a real threat to individuals, organizations, and service providers. Nevertheless, there are defences that can be put in place to minimize and mitigate these threats [6].

Although academic research in mobile device and smartphone security has been conducted for several years now, it's only recently—due to the explosion of mobile device deployment in the enterprise environment—that those
research activities have truly focused on solving real-world security challenges [7].

In this study, Security technologies of IOS and Android are briefly presented and considered. Then, brief information is given about malicious apps and exploits. Lastly, discussion is concluded to answer that tight question in the light of security models investigation and evidences collected from current life.

II. EVALUATION OF SECURITY FACTORS

In this part of study, security factors that have chosen for comparison are evaluated.

A. Application Distribution

App Store is the only place to distribute apps. Therefore, the apps must be uploaded that official marketplace for public. Before this process, developer must register with Apple and gets aware of license conditions. After registration, digital certificate can be obtained to sign app for distribution. Aim of digitally signing is to guaranty that both the identity of the app’s developer and the app are not modified, and that app is belongs to intended developer. Second important step to publish app is vetting process. Vetting process is process for checking application for privacy and security violations [8]. That process can be taken one or more weeks. Also, some other issues that may get developer into trouble are explored during this process. For example, the app that works with public web site in real time needs to be confirmed its own End User License Agreement (EULA) by users and web site moderator must check and decide the content that send over that app to publish or not.

For Android, users need to create account on Google Play as a publisher like Apple. But signing and vetting processes in Google Play are different! Android does not require the applications’ developers to sign apps with Google-issued signing certificates. Actually, developers who want to post their apps on Google are able to create as many self-signing certificates as they want without being monitored by Google [9]. That leads to some security vulnerability such as attackers can use famous company name to fasten their malicious app distribution. Also, vetting process in android is shallow and automatic means not checked by human beings. This situation gives easy way to put malicious apps on this trusted domain play.google.com. Also, there is more important issue here Google Apps (APK Files) can be published over anonymous web site or over e-mail. That totally leaves the decision to consumers for installation. But, one central problem is the inability of users to make good security choices and awareness [7].

B. Reduced Attach Surface

The attack surface is the code that processes attacker-supplied input. If app has vulnerability in some code, and either the attacker can't reach it, an attacker cannot base an exploit on this vulnerability. Therefore, a key practice is minimizing the amount of code an attacker can access, especially remotely [10].

For example, flash has a history of security vulnerabilities and not available on IOS. Android is still going on support it. In addition, there are vulnerability occasions reported about PDF viewer on Android such as some script in PDF performs dropper functionality. But, IOS render PDF files natively, only some features of it parsed. That reduces the number of potential vulnerabilities.

Also, security problem of WebView has been studied before and still exists [11]. Interestingly, research has shown that the WebView technology can be further exploited to break the sandbox protection mechanism in the underlying mobile OS. More mobile applications that integrate WebView, the broader the attack surface will become [7]. This problem is closely pursuing by these tow big companies.

C. Privilege Separation

Both IOS and Android kernel implements a privilege separation model like on UNIX system. In privilege separation model, mobile operation system requires every application run with its own group and users. Thus, this ensures that applications have no permission to access other applications. The most important system processes run as a root that is most important privilege. Usually, phone manufacturer use this root right for system apps. Applications you are downloading from store will run as mobile. An attacker who gets full control of the app such as the PDF viewer will be constrained by the fact the code she is executing will be running as mobile.

D. Permission-Based Access Control

IOS permission mechanism is quite different from Android. When application requires use of some other application or service feature at runtime, IOS asks the user about allowing requested access to intended resources. In IOS, predefined limited sets of permissions are given to third party apps. And, accessing to many of devices’ subsystems is blocked. In that, IOS don’t leave some important security sensitive decisions to user.

For Android, inside the application manifest there is a static list of permissions that is shown the user during installation process. Then, users decide to accept or deny of these permission requests. By the way, users cannot partially select permissions, in that all or not. If users don’t allow this permission request, installing will be stopped.

E. Sandboxin

IOS and Android sandboxing mechanism sometimes called isolation almost similar where each application is separated from other applications and system’s kernel. Isolation limits a process’s ability to access sensitive data or system resources from another process. Still, there is slight difference between them. In Android, each application is given permissions to access certain resources, and the isolation system prevents
accessing resources beyond the approved permissions. In IOS, developer himself can’t define permission mechanism. It is mean that there are certain access rules defined by IOS that takes over some responsibility from end users shoulders. IOS isolates some apps from the in-out email boxes and the SMS of a device. For instance, apps cannot send SMS without the users’ involvement. Of course, apps can still access some resources on the system. Thus, an attacker can use a malicious application to steal private information such as the device’s unique ID, sending email spam, or performing an off service (DoS) attack on the device [8]. In Android, some ways are also open for attackers. For example, app list can be retrieved by another app using certain permissions. And, files on SD (Secure Digital) card can be read and modified by an app without any restriction.

F. Data Encryption

The features of this dimension interest about how to protect the user data. In IOS, generally there are two-protection mechanisms that are hardware security and data protection. Every IOS device has a dedicated AES 256 crypto engine implemented in silicon usingUID and GID as key. Integrating these keys into the silicon helps prevent them from being bypassed or accessed. The UID allows data to be cryptographically tied to a particular device. For example, the key hierarchy protecting the file system includes the UID, so the files cannot be accessed if someone moves the memory chips from one device to another. In addition to the hardware encryption features built into IOS devices, Data Protection technology is used to further protect data stored in flash memory on the device. This feature use Hardware Key and Passcode Key. Data Protection is automatically enables by setting up a device passcode. In addition to unlocking the device, a passcode provides entropy for certain encryption keys. This means an attacker in possession of a device can’t get access to data in specific protection classes without the passcode. Besides, IOS keychain securely store passwords and other short but sensitive bits of data, such as keys and login tokens. Keychain data is protected using a class structure similar to the one used in file Data Protection [12].

For Android, data encryption likes IOS with a few missing. Android encryption mechanism is not powerful and sophisticated as IOS. Basically, there is no hardware level encryption and for file protection it uses 128-bit AES. Also, it is hard to guarantee that the file system encryption is enabled. So, this feature selected by the user.

G. Data Execution Prevention and Address Space Layout Randomization

DEP (Data Execution Prevention) is the another layer for security in IOS where a processor can distinguish which parts of memory can hold executable code and which parts are data. In that, DEP just allow execution of the code not the data. That hardens attacker mission. For example, when an exploit tries to run a payload that is injected into the process, DEP prevent data from execution. There are one way to bypass DEP is to use ROP (Return-Oriented Programming). In ROP, attackers harness existing valid code in memory to perform desired actions. However, to do this, they need to know where the code segments they want to reuse are located. Address space layout randomization (ASLR) makes this difficult by randomizing the location of objects in memory. Also, writing large payloads in ROP is very time-consuming and complex. This makes exploitation of IOS more difficult than just about any other platform [10].

In Android, before version 4.0 there is not this kind of special security layer. On the other hand, Android leaned on code signing and memory management unit to restrain attackers from reaching intendent memory location. But, after version 4.0 android implemented DEP and ASLR in its system core.

H. Geo-Location and Auto-Erase

Geo-Location is very useful feature to locate your phone in case of lost. Apple as a feature of its operating system and accompanying online service provides this feature. Our smartphones carry with them lots of sensitive data that, in the wrong hands, is capable of being used for identity theft and fraud. For this situation, auto erase come to help. If your phone is stolen or lost you can wipe your personal sensitive data from your phone. When this feature enabled 10-failed passcode attempts will automatically erase all data on the device.

For Android, there is not native solution. But there is third party apps on market.

III. MALICIOUS APPS

The cybercriminal motivations behind mobile malware may vary from collecting confidential data to financial gain. The three main motivations behind mobile malware include obtaining financial gain, collecting sensitive data without a user’s knowledge or approval, leave a security hole in the device and accessing private networks. Also, mobile-malware functions include activity monitoring and data retrieval, system modification, and unauthorized dialling [4].

As given in evaluation of security factor, Android is the most susceptible OS for threats and attacks. The authors in [14] stated three foremost explanations aspects for that: the shortage in reviewing for applications in Android official market, the openness and the compatibility with other smartphones Apps [5]. On the contrary, in Apps Store, there is a strict process to review and sign Apps before accepting it. Also, IOS is less openness and less compatible with other third parties Apps.

Malware has significantly increased, and writers of mobile malware are targeting mostly the Android platform. The most frequently targeted mobile platform in 2013 was Android with 79%, compared to 0% threats with IOS [15]. According to McAfee, a 30% increase in the number of attacks targeting the
Android operating system was detected. Moreover, out of a total of 8,000 mobile malware, Android threats make up 7,000 [16]. Of course, this statistic belongs to 2013-2014 years. As we consider the previous section, IOS and Android have been enhancing their security technology and adapting against new threats.

In sum, it can be said that most important malware attacks are related with social engineering, because user does not know what is really happening when installing new software. For this reason, Apple is making an effort to get this risky and heavy duty from user’s shoulders according to Android.

IV. DISCUSSION AND CONCLUSION

The growing popularity and sophistication of mobile platforms have made security and privacy a major issue for everyone, since these devices welcome every need that a PC offers. To cope with this concern, mobile operation system vendors have been improving new techniques and technologies. Majority of these are evaluated in this study. Operation system of two giant technology providers Apple and Google are almost same in case of technology. But, in approach manner Android have a few problem. Which are signing process, permission system drawback in case of social engineering and quick vetting process. For IOS, these concerns are handled very well. Besides, App store is only place to download app.

In this study, frankly it is not tried to answer which platform is more secure. Main goal here is to open a discussion for future works.

REFERENCES
An Evaluation of Some Instant Messaging Applications (Signal, Telegram, Threema) in terms of Security

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Abstract—With the development of technology, the usage of the internet via mobile devices are increasingly widespread. At the same time people generally use the internet to contact with their environment. So instant messaging applications operating with internet have become very popular, therefore they are in competition with each other. In this paper, Signal, Threema and Telegram among the most popular commercial instant messaging applications that allow users to messaging each other safely are handled in terms of security. Although these applications use telephone numbers as contact list, calls and messages use data connection, therefore both of the two users talking to each other must connect to internet. Thus, users can send messages without expose to fee of SMS or MMS. Although these applications are practice and fast, they have some security problems arising from the usage of the internet. So unauthorized users (attackers) can access user conversations by using fake identity. To prevent this situation, some authentication techniques are used in these applications. In this study, these authentication techniques are examined and when the user’s public key changed, what changes have occurred in the application are tested. Also whether these applications have vulnerabilities against the MitM (Man in the Middle) attack or not is detected, and also the shortcomings of these applications are evaluated from an ordinary user perspective.

Keywords—instant messaging applications, Signal, Threema, Telegram, MitM, Authentication

I. INTRODUCTION

Instant messaging (IM) is kind of an online messaging which offers users to communicate each other in real-time. IM has become very popular recently. It is used more than SMS worldwide. The number of IM accounts were over 3.2 billion in 2015 [1]. It is estimated that this figure will reach over 3.8 billion over the next four years [1].

When the topic comes to internet, IM applications bring some security problems. The users of IM applications don’t want anyone to read or modify their private conversations. There are some possible threats for these applications, the most important are government intelligence, curious family or friends or neighbors etc., analyzing messages for targeted advertisements etc. So, the instant messaging applications are divided into non-secure (not end-to-end) and end-to-end encrypted. The non-secure IM examples are Skype, Viber, Line, Telegram (it has both non-secure and secure form) etc. The end-to-end encrypted IM examples are Signal, Threema, Telegram (secret chat), WhatsApp (recently added) etc. In this study we compare Signal, Telegram and Threema among some popular secure IM applications in terms of security. Our main purpose is to detect which application is the most secure against the MitM attack. MitM is type of an attack based on the principle of seeing unencrypted data or data capture by entering between the victim computers and the other network tools [7].

II. INSTANT MESSAGING APPLICATIONS

A. Signal

Signal application supported by Android and IOS operation systems is free and open source software application allows users to send message to each other, to do encrypted calls, to send photograph and video with end-to-end encryption. After the application installed from the store of the device, in first step the screen of registration and phone number confirmation are seen as shown in Fig. 1.

Fig. 1: The registration screen and confirmation code in Signal application
When a phone number is entered and a button namely “Verify this device” is pushed, SMS-OTP consists of six digits is sent to user to confirm the phone number. After the confirmation code is entered to shown area, the user can start using Signal application. To use Signal as bilateral contacts, the application has to be installed in the devices of both sides. Encrypted and non-encrypted messaging can also be done in Signal. When messaging with persons exist in contact list or talking unauthentically, this application is not differ from the standard messaging application. For encrypted messaging, QR code is scanned. In this operation, a person’s identity verification is done through the barcode system. When clicked the user name which exists contact list, in upper right corner of the interface, “Conversation Settings” is exist as shown in Fig. 2. When entering the conversation settings, the option of “Verify identity” is located. Thus the user can be verified with this option.

As soon as clicking on the authentication section user’s self identity and identity of a person who wants to communicate with this user are listed and the user can reach to QR code from there (Fig. 3). After a user’s QR code as shown in Fig. 3 is scanned by the other user’s device, there is a unilateral authentication operation. Likewise when user select the option of “scan the QR code”, the QR code of the other user is scanned via the barcod reader. An example of QR code reading operation is shown in Fig. 4. If QR code is read truly, the user gets a confirmation message.

The other user confirms the opponent user’s QR code. If a user’s QR code confirms and one of the other QR codes is tried to confirm, Signal application gives "Conflict" alert to the user (Fig. 5).
After the confirmation operation, this users can messaging each other as encrypted. As well as the feature of encrypted messaging, another feature of Signal is that the feature of screenshot is not active as default. This feature is opened and closed as optional. According to us, this operation can be a security precaution against copying (phone number, the screenshot of any user’s QR code etc.). Also when a user suspects from the privacy of messages, he/she can do session reset easily (Fig. 6).

In an encrypted conversation, the most secure way of confirmation of the user’s identity is that co-words should be compared with a different confirmation way except from this communication traffic (in other words out of the communication band). Also if the user can recognize the voice of the opposite person, he/she can be done this operation by reading words an audible form through the phone.

**B. Telegram**

Telegram is a free application and it has both Android and IOS support. For it is faster than other instant messaging applications, Telegram has come to forefront when compared with others. Because it works cloud-based it is given right of access to last correspondences in seconds on any platform. As well as opportunity of setting up a group with 200 person by starting secure session, it enables to sharing videos in size of 1 GB. Telegram application has common usage because of these features is installed in a device to test. After the installation is completed, the user is verified with phone number and verification code (Fig. 8).
As the other chat applications, Telegram can be used in authenticated and unauthenticated form. In Telegram, secure messaging can be started as shown in Fig. 9.

In Telegram, users can only verify by sending screenshot of their symmetric encrypted keys (Fig. 10). When compared with Signal, ensuring this verification as a manual way raises doubts about the reliability of Telegram application.

C. Threema

Threema is a paid software presented by Kasper Systems GMBH. It has both Android and IOS support. After the installation of this application, it is clicked to “Set up Threema” button and the operation fingerprint generation is started as shown in Fig. 11.
When the application is installed, the first part of attracting to user’s attention is orange dots existing next to each user’s name (Fig. 12). By default, user which hasn’t any confirmation are shown as two orange dots.

According to confirmation level it changes to green in maximum security level. As in the other applications, it can be messaging in protected and unprotected form. Threema claims that messages between users are protected with end-to-end encryption. In Threema, the authentication is done with QR code identification asymmetrically. Users can see their QR code and have to be scanned by opposite user as shown in Fig. 13. This picture represents the QR codes of two different users. When these QR codes are scanned accurately by barcode scanner, the application sends user a confirmation info. Like in Signal, when different QR code is scanned for the same user, Threema sends user a conflict alert.

After the user’s identity is verified, the three dots which are located next to the user’s name in contact list are seen completely green. This view indicates that the user communicates with other users through encrypted line. In the same way after the other user performs verification, the authenticated user in his list and unauthenticated users are shown green and orange dots respectively. Thus the user can enabled to distinguish authenticated and unauthenticated user (Fig. 14).

III. SECURITY COMPARISON ANALYSIS OF THE APPLICATIONS

In this section we analyse these three applications in terms of security. With the purpose of observing that how the system reacts when one of the users changed his/her public key, one of the users removes his application and installs again. The opponent side doesn’t do any change. When the user (Isil) installed again the Signal application, her public key changes automatically. Previous encrypted conversation conducted with Ugur via his earlier authentication are saved in both devices of Isil and Ugur. When Isil sent message to Ugur with her new public key, this message isn’t delivered and some warning messages are sent to Ugur as shown in Fig. 15.
As seen in Fig. 15, the warning message about changing of Isil’s public key is notified in Ugur’s device. But in this point the missing part is that Isil doesn’t aware of this situation. She sees that he sent messages to Ugur are correctly delivered. Similarly the alert can be given to the user Isil, the opponent side until he verified new public key, the warning in the form of "this user hasn’t verify your public key yet" can be given.

In Signal, after mutual authentication has been done, the same users can not do unauthenticated conversation with each other. Therefore the messages of the user Isil changing her public key are not delivered without authentication by Ugur. Even except private messaging, encrypted group chat is opened and still Ugur doesn’t see the messages of Isil. This is a good way to prevent Man in The Middle (MitM) attacks.

After Ugur verified Isil’s identity, no longer Ugur’s messages are delivered to Isil in Signal. To be attacked by fake users in Signal is related to user’s attention. Because the message that is about Isil’s changing public key is delivered to Ugur but it is doubtful whether this user is real Isil or not. An attacker can copy the number of Isil and install Signal. In such a case to be sure Ugur should send e-mail to Isil to notify this situation, he need to confirm whether this user is really Isil or not.

From the perspective of both user authentication of Signal and giving warning message to user when the other user changes her public key, Signal is a secure chat application. Also the verification of the public key is realized by barcode scanner professionally. This is one of the superior aspects of the program. In addition, even if the user changes her/his public key (when she/he removed application and installed again), old messages are stored in Signal.

InTelegram application providing secure messaging with end-to-end encryption, because there is no authentication between users, the application works with the principle of trust to server. Encryption is performed between client and server, hence Telegram is imprudent against the MiTM attacks. Even the server has the potential to make this attack.

The negative aspects of Telegram application, when one of the user removed application and installed again, encrypted messages done with opponent side are deleted in both side. This situation doesn’t requested by clients. Secure session can be opened again without any authentication with the desired users and messages can be transmitted to the other side. So Telegram has not taken any precautions to prevent the imitation the client. Although this application is quick and practice, for there is no authentication between clients, we evaluate Telegram as an insecure messaging application.

In Threema, when one of the users changed her/his public key, a second user which has the same name is added to contact list to other side. The second user’s security level is low than the previous. The user’s old session stays as the same and the verification level of Threema id verified with the user’s old public key remains as green (Fig. 16).

The scenario in Fig. 16 while Isil has 482VCAHU id, the QR codes are scanned with Ugur mutually and the authentication process is completed. Then when Isil changed her public key, two different record in the same name which has different IDs has been seen in Ugur’s device. Isil’s new ID has changed as FS87P8H4. When Isil wrote message to Ugur with her new public key, the message transmits from insecure channel indicated with orange. So authenticated id and unauthenticated id coming from the same phone number are showed like two different users in contact list of the opponent side. We think that this application is secure against MiTM attacks because of these properties of the Threema. But for some features are not clear and due to be paid, Threema lost the feature of the interaction. A warning of changing the user’s public key should be given even one time but it shouldn’t allowed to automatic
verification. Another drawback is the lack of encrypted or unencrypted calls. The user’s public key exchange can be done by removing the application or reset the application with Delete ID option.

IV. CONCLUSION

In this study, we focus on Signal, Telegram and Threema among secure instant messaging applications, we evaluate usage patterns of these applications and we also test the applications by secure signing in or without adding security. Also when someone’s public key changed from two people during the communication, we examine occurring changes and make inferences about whether the application is safe against MitM attacks or not.

In Signal and Threema, thanks to QR codes, imitating any client is prevented but this precaution is not exist in Telegram. One of the disadvantages of Telegram is that uses symmetric key structure and any authentication is not performed between clients. If users want to share their encrypted keys with each other, they send the screenshot of their barcodes. The result of changing user’s public key Signal and Threema has taken security precaution by changing the user’s QR code. The information of the user’s public key exchange is delivered to opponent side in Signal, but such a warning message is not given and the messages of the user’s changing public key are transmitted from insecure channel in Threema. Also if the other user wants, the user’s new public key can be verified without re-matching QR code. Although this feature provides convenience in terms of the user, it can create sense of danger against copies phone numbers. For there is no such right in Threema, users need to meet face-to-face or via e-mail to re-verification their public keys of each other. They have to send their QR codes to each other. Due to this feature, there is slightly lack of user interactive in Threema. The balance between adding security and being user interactive is very important for such applications.

As a result, if we sort these applications according to security level, a free software Signal is evaluated in first rank when compared to the other two applications in terms of security and user interaction because of it’s secure group messaging, encrypted conversations and practice solutions presented to opponent user when another user’s public key changed. Threema is located in second rank, due to the situations of being paid software, the lack of calling feature and not giving a warning message to user as result of changing the public key. And finally Telegram is located in last rank in terms of security due to the lack of mutual authentication system and the use of symmetric key. Although the symmetric key is much faster than the public key, it can be broken more easily.

REFERENCES

Preparing Diet List Suggestion with Fuzzy Expert System

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Abstract— Proportion of disease is growing due to the malnutrition and sedentary life. In this work, a diet list is proposed to the user by calculating the necessary amount of calorie according to gender, weight, height, age and activity level. Diet list are prepared for seven days of a week as divided by six meals. Parameter assessment of users and offering recommendations are made via fuzzy expert system. Prepared diet list are constituted considering calories of nutrients and based on the dieticians’ general diet list proposals. Developed software also includes some functions such as nutrition advices, calculation of ideal weight, information about benefits of several nutrients and calorie evaluation of some daily activities. Thus, nutrition suggestion software carried out against for growing obesity and healthy eating problems in order that people would educate themselves about wellness.

Keywords— Diet list, fuzzy expert systems, nutrition, nutritional value.

I. INTRODUCTION

European office of World Health Organization (WHO) pointed out in “European Food and Nutrition Action Plan 2015–2020” that malnutrition, obesity and unhealthy diets lead to noncommunicable diseases (NCDs). Also, these cause economic and social costs for individuals, families and countries. In the same report, about %57.4 of people over the age of 20 are reported as overweight or obese. Action plan that further analyzes given in this report is about implementation of healthy diet and controlling the food productions with the aid of governments [1]. Besides all these, diabetes, hypertension and high cholesterol are among the top 10 causes of death in the world [2].

Every nutrition plays an important role for supporting daily activities of the people. Therefore, a balanced diet should be in proportion to the values of carbohydrate, protein, fat, vitamins and minerals. Values of these nutrients should be calculated by taking into account taken and consumed energy. Nevertheless, people do not prefer allowing time to go dietician because of their habits and busy schedule. To overcome this problem, web or pc based expert systems that have input parameters such as current diseases, activity level and age should be used.

There are many studies which are focused on diet planning for humans. Some of them are focused on a specific region or a situation. Kljusurić et al. [3] presented a nutrition planning system using fuzzy logic modeling method for boarding schools in Croatia. Daily menu price, meal preference, nutritional and energy value of foods considered input parameters. They take meal preference as input since nutrition habits are different in various places of Croatia. Their software is suitable for planning of menu which has optimal cost and adequate nutrient intake. Kurozumi et al. [4] proposed a Japanese diet evaluation system that uses Fuzzy Markup Language and food exchange list published by Japan Diabetes Society. Dietary healthy level is evaluated by calculating the nutrient percentages of foods selected for menu and proposed method according to the Japanese dietician database. Another region specific work is presented by Şahiner et al. [5]. They examined how to prepare a sample weekly menu for a young person who has a business environment that requires intensive physical activity and his revenue determined by Türk-İş (Confederation of Turkish Trade Unions) on the edge of hunger.

Faiz et al. [6] implemented an approach that gives diet and exercise recommendations for diabetes by using Web Ontology Language and Semantic Web Rule Language as a specific human case application. Similarly, Li et al. [7] proposed automated food ontology for diabetes that cares necessary nutrient values and limitations. They used Hierarchical Clustering Algorithms, Class Naming by intersection naming and instance ranking by granular ranking and positioning so as to construct various food groups (diet lists). Another work considers the diseases were presented by Chen et al. [8]. An diet recommendation was offered by using Fuzzy Rules and Knapsack Method that utilizes users’ height, weight, activity level, renal function, hypertension, high cholesterol and preference data. Mamat et al. [9] proposed Fuzzy Multi-Objective Linear Programming application that provides an optimum diet list includes enough nutrients for a day with reasonable price. Decision Support System also used in this work to recognize the type of disease according to the symptoms obtained from the users.

Main method used in the diet assessment systems is Fuzzy Logic and its derivatives. Lee et al. [10, 11] produced Type-2 Fuzzy Ontology based on Type-2 Fuzzy Food Ontology and Fuzzy Markup Language-2(FML2). Similarly, they presents to the user healthy level of the foods in diet with semantic expressions by developing FML2 based agent. Mamat et al. [12] made a balanced diet planning using Fuzzy Linear
Programing approach. In this planning, assessment of carbohydrate and fat amounts in the food that eaten every day, food prices and the amount of nutrients that required to take a day are for 30 years old sedentary woman considered. Mạ́k et al. [13] have presented an equation that define dietary and physical activity advisory problem. Proposed equation expressed as “Hierarchical Multi-Objective Dietary Menu Planning Problem with Harmony” allows the formalization of any diet and physical activity planning problem.

When we interpret the proposed works we deduced that there is a necessity for a software support to the diet list preparation. Another argument is usefulness of fuzzy logic based expert system since input parameters for diet and outcome presentation are verbal. Also, diet is a multi-parameter process should vary according to the individual and cultural characteristics. In this paper, we calculated adequate parameter process should vary according to the individual and cultural characteristics. In this paper, we calculated adequate calories in proportion to the person’s gender, weight, height, age and activity level parameters by using fuzzy logic. After calorie determination software presents one diet list that previously prepared. This diet list arranged according to the food culture and presence in related area.

II. NUTRITION AND BASAL METABOLISM

A. Nutrition

Nutrition is a conscious activity, taking nutrients needed by the body adequately and on time, to protect the health and improve the quality of life. Taking every item of the energy and nutrients that essential for growing-regeneration and working of the body and proper use of them in the body is called “Adequate and Balanced Nutrition” [14].

Nutrients that we need for healthy and balanced diet can be collected in 5 main groups as shown in Fig. 1.

When we examine the pyramid, we should say that grains are most preferred nutrient group. Hereinafter vegetables and fruits come. Milk and dairy products with meat group foods follows this group. We should consume fat and sugar group at least [14].

We can group the animal and plant nutrients according to the chemical properties as follows:
- Carbohydrates
- Proteins
- Fat
- Vitamin
- Minerals
- Water

There are similar or different features of each food group which are necessary for the body. Healthy eating achieved by taking these nutrient groups adequately and balanced as mentioned before.

1) Carbohydrates

Carbohydrates are used as primary energy source of body and it is important for brain functions and nervous systems. The building blocks of carbohydrates are glucose. It can be divided as monosaccharides, disaccharides and polysaccharides. Also while the most common dietary disaccharides can be divided as are maltose, lactose, and sucrose, the most common forms of digestible polysaccharides are amyllose and amylopectin. Monosaccharides and disaccharides are found in such food as fruits, vegetables, milk, milk productions, sugar and sugar products. And, as for polysaccharides, they are found in such food as cereals, bread, pasta, rice and potatoes. Glucose is stored as the form of glycogen in the liver and mostly skeletal muscle [15, 16].

2) Proteins

Proteins are related with all forms of plant and animal life and 20 percent of our body is composed of protein. Proteins form the structure of each cell of our body tissue, muscle, internal organs, tendons, skin, hair and nails. And it also used for energy productions as a fuel in such metabolic formation activations as growth, formation of new tissue and repairment of tissue damaged. Besides it is necessary for the production

![Fig. 1 A healthy eating pyramid [15]](image-url)
of many enzymes, hormones (adrenaline and insulin) and neurotransmitters. In addition to that it has important role in the protection of fluid balance in tissues, the transition of nutrients into cell sand out and making the blood. Protein is composed of 20 amino acids and these amino acids are grouped as essential amino acids and non-essential amino acids [15, 16].

3) Fat

Fat can provide more than twice the energy by weight compared to protein and carbohydrate and it is essential macronutrients which have most energy dense. Fat provides energy production, insulation against the cold, transportation of fat-soluble vitamins in the body and making the body tissue. Fat is grouped as saturated fat (butter, margarine), monounsaturated fat (olive oil, soybean oil, fish oil) and poly unsaturated fat (sunflower, corn). Especially, saturated fat increases the amount of fat in the body. There are a lot of fat in such food as meat, fish, milk, cream, eggs, nuts, chocolate, olive, coconut, cottonseed, corn, soybean, flax and peanut [15, 16].

4) Vitamins

Vitamins cannot be synthesized by the body, are required to support health and well-being. Vitamins are found in small amounts in foods and are designated as nutrients. They help catalyzing the numerous biochemical reactions and aren’t used for direct source of energy. Vitamins are grouped as Water-Soluble Vitamins and Fat-Soluble Vitamins. B group vitamins and vitamin C are the water-soluble vitamins. Unlike the fat-soluble vitamins, they leave the body after completing their task; they don’t accumulate in the body [15, 17].

5) Minerals

Minerals, occur naturally, are inorganic solid with a specific chemical composition. The properties of minerals can be listed as follows:

- It occurs naturally.
- It has the characteristics of any part of the whole.
- It has a specific chemical formula.
- It is solid but rarely fluid.
- Inorganic.

The chemical compounds obtained synthetically in the laboratory do not considered as mineral with the technological progress. These types of solid materials are named as artificial minerals. Each mineral have different features for the body and the features of some minerals are described. Iron is the necessary element for the delivery of oxygen to tissues and the use of oxygen at the cellular and subcellular levels. Magnesium is required in a variety of cellular activities that support diverse physiologic systems. Zinc is necessary for more than 300 enzymes activity. Chromium is the essential mineral for regulation of glucose, lipid and protein metabolism [17, 18].

6) Water

The water is abundant in the world, indispensable for life, odorless and tasteless compound. The amount of fluid we need to take daily is associated the calorie we spend. 1 ml water should be taken per calorie. Water is the essential element for life and it helps to control of body temperature, use of

<table>
<thead>
<tr>
<th>Food</th>
<th>Calorie</th>
<th>Protein</th>
<th>Fat</th>
<th>Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trout</td>
<td>168</td>
<td>18.3</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Perch</td>
<td>93</td>
<td>19.2</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>Beef Meat (Low Fat)</td>
<td>156</td>
<td>19.7</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Sausage</td>
<td>452</td>
<td>21.4</td>
<td>40.8</td>
<td>0</td>
</tr>
<tr>
<td>White Chicken</td>
<td>114</td>
<td>23.2</td>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>Broad Bean</td>
<td>338</td>
<td>25.1</td>
<td>1.7</td>
<td>58.2</td>
</tr>
<tr>
<td>Haricot Bean</td>
<td>340</td>
<td>22.3</td>
<td>1.6</td>
<td>61.3</td>
</tr>
<tr>
<td>Lentil</td>
<td>340</td>
<td>24.7</td>
<td>1.1</td>
<td>60.1</td>
</tr>
<tr>
<td>Chickpea</td>
<td>360</td>
<td>20.5</td>
<td>4.8</td>
<td>61</td>
</tr>
<tr>
<td>Pea</td>
<td>348</td>
<td>24.2</td>
<td>1</td>
<td>62.7</td>
</tr>
<tr>
<td>Sunflower Seed</td>
<td>560</td>
<td>24</td>
<td>47.3</td>
<td>19.9</td>
</tr>
<tr>
<td>Almond</td>
<td>598</td>
<td>18.6</td>
<td>54.2</td>
<td>19.5</td>
</tr>
<tr>
<td>Walnut</td>
<td>651</td>
<td>14.8</td>
<td>64</td>
<td>15.8</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>634</td>
<td>12.6</td>
<td>62.4</td>
<td>16.7</td>
</tr>
<tr>
<td>Pumpkin seeds</td>
<td>610</td>
<td>30</td>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>Pear</td>
<td>61</td>
<td>0.7</td>
<td>0.4</td>
<td>15.3</td>
</tr>
<tr>
<td>Strawberry</td>
<td>37</td>
<td>0.7</td>
<td>0.5</td>
<td>8.4</td>
</tr>
<tr>
<td>Fresh Figs</td>
<td>80</td>
<td>1.2</td>
<td>0.4</td>
<td>20.4</td>
</tr>
<tr>
<td>Melon</td>
<td>33</td>
<td>0.8</td>
<td>0.3</td>
<td>7.7</td>
</tr>
<tr>
<td>Banana</td>
<td>85</td>
<td>1.1</td>
<td>0.2</td>
<td>22</td>
</tr>
<tr>
<td>Okra</td>
<td>36</td>
<td>2.4</td>
<td>0.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Potato</td>
<td>76</td>
<td>2.1</td>
<td>0.1</td>
<td>17.1</td>
</tr>
<tr>
<td>Fat White Cheese</td>
<td>289</td>
<td>22.5</td>
<td>21.6</td>
<td>0</td>
</tr>
<tr>
<td>Cheddar cheese</td>
<td>404</td>
<td>27</td>
<td>31.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Whole Milk</td>
<td>61</td>
<td>3.3</td>
<td>3.3</td>
<td>4.7</td>
</tr>
<tr>
<td>Oil Yogurt</td>
<td>61</td>
<td>3.5</td>
<td>3.3</td>
<td>4.7</td>
</tr>
<tr>
<td>Egg</td>
<td>158</td>
<td>12.1</td>
<td>11.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Honey</td>
<td>315</td>
<td>0.3</td>
<td>0</td>
<td>78.4</td>
</tr>
<tr>
<td>Chocolate</td>
<td>528</td>
<td>4.4</td>
<td>35.1</td>
<td>57.9</td>
</tr>
<tr>
<td>Candy</td>
<td>385</td>
<td>0</td>
<td>0</td>
<td>99.5</td>
</tr>
<tr>
<td>Bulgur</td>
<td>357</td>
<td>10.3</td>
<td>1.2</td>
<td>78.1</td>
</tr>
<tr>
<td>Wheat Bread</td>
<td>276</td>
<td>9.1</td>
<td>0.8</td>
<td>56.4</td>
</tr>
<tr>
<td>Macaroni</td>
<td>369</td>
<td>12.5</td>
<td>1.2</td>
<td>75.2</td>
</tr>
<tr>
<td>Rice</td>
<td>365</td>
<td>6.7</td>
<td>0.4</td>
<td>80.4</td>
</tr>
<tr>
<td>Sunflower oil</td>
<td>884</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Margarine</td>
<td>736</td>
<td>0.6</td>
<td>81</td>
<td>0.4</td>
</tr>
<tr>
<td>Olive oil</td>
<td>884</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Butter</td>
<td>717</td>
<td>9</td>
<td>81.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Tomato paste</td>
<td>98</td>
<td>2.7</td>
<td>0.4</td>
<td>21.3</td>
</tr>
<tr>
<td>Black olive</td>
<td>207</td>
<td>1.8</td>
<td>21</td>
<td>1.1</td>
</tr>
</tbody>
</table>

| TABLE I       | CONTENT AND CALORIES OF SOME NUTRIENTS FOR 100 GR [19] |

Fluid intake must be increased to prevent dehydrations. Thirsty feel can be seen late in children and recommended amount of fluid are as follows to avoid of fluid loss for children:

- Up to 10 kg bodyweight → 100 ml / kg / day
- Up to 20 kg bodyweight → 50 ml (added for each kg) / kg / day
- Up to 30 kg bodyweight → 25 ml (added for each kg) / kg / day [15, 18].
Calorie, protein, fat and carbohydrate values of some nutrients can be shown in Table I.

B. Basal Metabolism

All the chemical changes that occur in the cell to sustain life is called “metabolism”. Metabolism covers all cell construction and demolition events. Mandatory energy expenditure for working of the organs, keeping body heat and keep living in the case of complete rest is called “Basal Metabolism” [20].

Several prediction equations were presented. Harris-Benedict equation created in 1919 was the most known. Mifflin St Jeor equation used for our work as follows:

\[ P = \left( \frac{10 \times m}{1 \text{ kg}} + \frac{6.25 \times h}{1 \text{ cm}} - \frac{5 \times a}{1 \text{ year}} + s \right) \]  

Where s is +5 for males and −161 for females, P is the total heat production at complete rest, m is the mass (kg), h is the height (cm) and a is the age (years).

Daily energy expenditure of individual determines his/her required energy intake for a day. Energy requirements for a normal person should be calculated by summing of the basal metabolism, need for daily physical activity and thermic effects of the foods. Energy need for sportive activities should be add this value for athletes. Thermic effect of the foods means that increase in the body’s metabolic rate that is produced by the consumption, digestion, metabolism, and storage of food. Increase in the body’s metabolic rate or energy consumption is about %3 for fat, %6 for carbohydrate and %16-20 for protein [15]. Energy expenditure of some activities can be shown in Table II.

III. DEFINITION OF FUZZY EXPERT SYSTEM

Expert system is software that provides solutions and suggestions by using knowledge and experience of an expert has skill in any area. Fuzzy logic is beneficial for taking linguistic values from the user. Expert systems have to include the 3 following units:

- Knowledge Database is an updatable structure which information is obtained from experts, books and other literature.
- Result Inference Mechanism should reach a conclusion by using rules in the knowledge database, facts and other whole information through the instrument of both forward and backward chaining method.
- User Interface uses the expert system and provide interaction between the user and system. Basic structure of a Fuzzy Expert System is shown Fig. 2.

IV. PROGRAM INTERFACE AND FEATURES

Main page of our software is shown in Fig. 3. Users input their personal information and desired values such as gender, workload, weight, height and age. According to this parameters required calorie determined and diet lists consonant with this value would be presented to the user. Software also includes enlightenments about several foods and vitamins. Additionally, user can calculate his ideal weight

<table>
<thead>
<tr>
<th>Activity</th>
<th>Burned Calorie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycling, 12-13.9 mph, moderate</td>
<td>563</td>
</tr>
<tr>
<td>Swimming butterfly</td>
<td>774</td>
</tr>
<tr>
<td>Watering lawn or garden</td>
<td>106</td>
</tr>
<tr>
<td>Walking 2.0 mph, slow</td>
<td>176</td>
</tr>
<tr>
<td>Carrying infant, upstairs</td>
<td>352</td>
</tr>
<tr>
<td>Playing tennis</td>
<td>493</td>
</tr>
</tbody>
</table>
and body mass index. Membership functions of female height which is one of the diet system inputs is shown in Fig. 4.

Diet list are prepared for seven days of week as divided by six meals. Diet list that previously prepared taking into account the calorie values of the foods and these are classified according to the fuzzy inference outputs. After required calorie calculation, relevant list proposed to the user.

V. CONCLUSION

Balanced diet should help users to prevent eating disorder such as anorexia nervosa, diabetes, and obesity. This study shows that application of fuzzy logic can be used to represent recommended energy and nutrient intake adequately, as well as to present acceptable price and preferences of menu selection for people in a specific region. Diet list is proposed to the user by calculating the necessary amount of calorie according to gender, weight, height, age and activity level. These lists are prepared for seven days as divided by six meals and constituted considering calories of nutrients and based on the dieticians’ general diet list proposals.

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REFERENCES


Switching Access Points on and off for an Energy-Efficient Wireless Communication

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Abstract— IEEE 802.11 wireless network standard has become one of the most used wireless networking technologies for smart devices as it offers mobility support and low cost deployment. However, these devices deeply rely on the energy provided by their batteries, which results in limited running time. In addition, condensed deployment of Access Points (APs), which is essential to handle increasing demand of performance and coverage, has also been causing rise of network-side power consumption. In this context, this paper proposes an energy-aware Access Point switching procedure for smart mobile devices to increase overall energy saving of both APs and smart devices. In the proposed method, each channel is investigated, in terms of channel utilization, signal quality, probability of collision and deployed traffic types, making use of local and IEEE 802.21-based management frames. With the help of reputation and context-aware computations, Access Points inform the stations that are associated with themselves to maintain their connection or to handover to another network. The aim of the proposed scheme is to maintain desired QoS with minimum number of APs and optimal energy consumption. Widespread simulations have been executed to validate the efficiency of the proposed method. The results demonstrate that the proposed method dramatically increases overall throughput and reduces power consumption of stations over IEEE 802.11 WLANs.

Keywords— IEEE 802.11 WLANs, IEEE 802.21, Load balancing. Energy efficiency, Handover

I. INTRODUCTION

Nowadays, wireless local area networks (WLAN) and smart mobile devices have an enormous amount of usage in daily life. The IEEE 802.11 WLANs [1] are widely deployed all around the world. However, due to design choices and requirements, communication range of the IEEE 802.11 WLAN standard is limited and large wireless network coverage is provided using several APs [2].

Since smart devices are mobile, stations on the move may lose their signals from their associated APs. In this case, stations attempt to retain their wireless connectivity by connecting to other APs in vicinity. Therefore, AP selection, a.k.a. handover operation plays a key role for the optimization of the wireless connectivity over the WLAN environment.

Handover is the procedure of shifting an ongoing call or a data session from one AP to another. Conventionally, handover is activated according to the received signal strength (RSS), such that stations select an AP that has the strongest RSSI. If AP selection is activated only by observing the RSS, it results in many stations associate with one of the APs as shown in Fig. 1. As a result, throughput of the heavily loaded AP decreases due to the congestion, while there are other APs available but not used efficiently. Therefore, a new algorithm which balances the load among APs is required to choose possibly the best AP from an available AP list.

Current energy-aware handover approaches succeed energy savings either by diminishing channel scanning time or by connecting to the most energy-efficient AP according to the traffic type. Yet, an energy-aware handover approach must contain more local and network related metrics, such as battery and interface information, application-specific QoS requirements, user preferences, number of stations connected to each AP, channel utilization ratio per AP, and etc. [3].

In line with the above-mentioned clarifications, this paper addresses an energy-aware AP switching on/off procedure for smart mobile devices. In the proposed method, each channel is investigated in terms of channel utilization, signal quality, probability of collision and deployed traffic types by making use of local and IEEE 802.21-based management frames. With the assist of reputation and context-aware computations, APs inform stations that are associated with themselves to maintain their connection or to handover to another network. Widespread simulations have been executed to validate the performance of the suggested method. The results demonstrate that it dramatically increases overall throughput and reduces power consumption of stations over IEEE 802.11 WLANs.
II. RELATED WORKS

There have been some works in the literature that addresses AP selection for infrastructure based IEEE 802.11 WLANs. Some of these works are either centralized or decentralized, or even based on new network policies. For instance, authors in [4] propose an analytical approach to regulate efficiency of policies that trigger APs in dense wireless environments based on real consumer demands, and then measure the performance that is accomplished by such policies in terms of energy savings and QoS.

In [5], authors study the issues of: What kinds of information will help STAs to select the best AP? and How should STAs select APs based upon the available information? To achieve effectiveness and fairness among APs, they propose a decentralized scheme that requires some adjustments both for mobile devices and APs. They study both dynamic selection and one-time selection structures. They evaluate both cases through simulations and show the improvement of total throughput and fairness.

Additionally, authors in [6] suggest a decentralized fair AP selection approach both for recent associated mobile users and already connected mobile users. The proposed scheme is a heuristic algorithm and realized only by adding one additional field in current AP beacon and probe frames. Furthermore, authors also demonstrate steadiness of their scheme. Authors in [7] discuss potential bandwidth as a metric; mobile user is likely to receive connecting to a specific AP. They offer a procedure for the computation of potential upstream and downstream bandwidth between mobile users and APs depending on delay measurements experienced by beacon frames.

Authors in [8] propose another method called Virgil, a pre-programmed AP detection and selection scheme. Virgil scans for all available APs in a vicinity, associates to them one by one, and initiate a battery tests to evaluate the quality of each AP’s connection.

Additionally, in order to increase energy efficiency of APs, sleep mode procedure is discussed by the authors in [9]. Their proposed scheme makes use of an auxiliary low-power radio to carry out-of-band control information to maintain connectivity and wake up the APs when necessary. This work also details the software and hardware architecture as well as the prototyping results on Wi-Fi technology.

Authors in [10] addresses the multi-rate issue frequently seen in WLANs. Multi-rate elasticity may result in low bit rate mobile users to undesirably affect high bit rate ones and subsequently damage whole network throughput. In this context, authors first develop a decision metric the selection can be based on. Making use of this metric, they suggest two new selection mechanisms that are decentralized in the sense that the decision is achieved by each mobile user, by given proper status information of each AP.

III. PROTOCOL DESCRIPTION

In IEEE 802.11 WLANs, a station has the right to select an AP which it will associate with. However, a station does not know the channel utilization rate, the number of associated stations to an AP, transmission rates of other nodes etc. Additional information is required for stations to consider the network utilization and to select the most appropriate AP. Since an AP is capable of having information of all the stations it has, AP can transmit information to the channel to indicate its own conditions by installing a proper algorithm. Beacon frames or probe response frames transmit information that contains the channel utilization and the number of station connected to the AP. However, a station requires more than this information to select the most appropriate AP. Besides, channel utilization information that is transmitted from an AP can be calculated mistakenly in the existence of both real-time and non-real-time traffic.

To obtain fast and energy-efficient AP selection, the proposed scheme utilizes beacon frames and IEEE 802.21 Media Independent Information Service (MIIS). Beacon frame is one of the management frames in IEEE 802.11 based WLAN standard. It holds related information about the network and allows stations to initiate and maintain communications. Additionally, the aim of the IEEE 802.21 standard [11] is to progress mobile user involvement by providing a Media Independent Handover (MIH) which supports both mobile-initiated and network-initiated handovers.

The MIIS supports the distribution of the network information and provides as many information as possible to the APs, such as the available APs and their coordinates (or the connectivity graph), the services they can provide and channel utilization ratios of APs [3]. Fig. 2 shows a sample of a distance-based connectivity graph given by the IEEE 802.21 IS.

![Figure 2. Distance-based connectivity graph provided by the 802.21 IS](image)

where $r$ is the transmission range of each AP, $d(n)$ is the linear distance between the $AP_i$ and $AP_j$. Using this information, users are able to scan only the channels the IS provides. Therefore, users are also able to diminish total scanning time, reducing the channels that are not in the connectivity graph.

Decreasing total number of channels that will be scanned lets mobile users to enable fast and energy-efficient channel
scanning. Nevertheless, throughout the handover procedure, connecting to an AP that is expected to consume the least amount of energy among all APs is also as important as the fast handover. Therefore, we also propose an energy-efficient handover scheme, which calculates the expected amount of power consumption per AP, by utilizing the Channel Busy Times (CBTs) and the number of stations deployed in each AP.

CBT is the fraction of time that the wireless channel is busy within a given interval. CBT can be calculated by each mobile device distributedly through summing the time utilized by the transmission of all data, management, and control frames in the network. Consequently, CBT of a data frame that has a size of \( S \) bytes and a transmission rate \( R \) can be computed as follows, 

\[
CBT_{data} = \frac{T_{DIFS} + T_{data}(S)(R)}{T_{cy}}
\]

CBT of an ACK frame is computed as follows, 

\[
CBT_{ACK} = \frac{T_{SIFS} + T_{ACK}}{T_{cy}}
\]

CBT of a beacon frame is computed as follows, 

\[
CBT_{bf} = \frac{T_{DIFS} + T_{bf}}{T_{cy}}
\]

Finally, the total channel busy time \( CBT_{total} \) within a specific interval \( t \) can be calculated as, 

\[
CBT_{total}(t) = \left( a(t) \times CBT_{ACK} \right) + \left( b(t) \times CBT_{bf} \right) + \sum_{i=0}^{\infty} CBT_{data}(S_i)(R_i)
\]

where \( a(t) \), \( b(t) \) and \( c(t) \) are the numbers of ACK, beacon and data frames that are encountered within a specific interval \( t \), respectively. Accordingly, channel utilization percentage \( U(t) \) within a specific interval \( t \) can be computed as, 

\[
U(t) = \frac{CBT_{total}(t)}{t} \times 100
\]

With this computation, mobile devices can compute channel utilization rates of their APs within a specific interval distributively. Nonetheless, this computation is impractical for devices as it requires continuous processing overhead, prevents devices to be in the doze state and rises the power consumption. However, in the proposed method, APs are responsible for computing the CBT values within a specific interval. For instance, Atheros AR5212 chipset maintains 32-bit register counters to track the “medium busy time” and the “cycle time”. These counters give the fraction of time that the wireless channel is busy (CBT) per second [12]. Likewise, in the proposed method, we assume each AP computes and updates its CBT periodically with one-second intervals and then, delivers this information with the IEEE 802.21 IS. Whenever a device initializes its network discovery phase, the IS informs the station about the number of stations in available APs and their CBTs along with the connectivity graph. The information of the CBT and the number of stations per AP along with the RSSI values obtained in channel scanning are used to compute the expected amount of power consumption of the device for every possible association scenario with available APs in vicinity. Subsequently, the proposed method allows mobile devices to associate with APs that are expected to consume the least amount of energy among all APs.

Since unsaturated (e.g. UDP) delay sensitive stations have different characteristics and requirements, E-model conversational audio quality factor \( R \) is also used to estimate the perceived voice quality for real-time VoIP applications. Association of a new station to the AP affects the voice quality of other stations associated to the same AP. For an unsaturated station, there are many factors that may affect the selection of the right AP. R value, capacity utilization, transmission rate, fairness, hidden nodes and the number of associated stations to an AP are some of these factors. Existing beacon or probe response frames do not contain all of this information. A new algorithm that also considers all of these factors explained above is required for the best AP selection for unsaturated stations. Therefore, a few bytes of extra status information have to be added to the beacon and probe response frames. Since it is only a few bytes of information, it does not affect the overhead significantly but it improves the voice quality and overall throughput.

In this context, APs will transmit a beacon or probe response frame which contains three additional items; an average R value of the stations in AP, a new estimated average R value if the station selects the same AP and the possible R value of the station which is trying to associate with the same AP. Then, the station will receive the enhanced beacon or probe response frames from APs and consider the best AP selection by looking at the RSSI value as well. Besides, an AP which has less station due to different traffic types and frame sizes can be more loaded than other APs which have more stations. That’s why fairness is not only about the number of stations associated to the APs. The main point of this study is selecting an AP of a station to have a higher voice quality. Improving the voice quality also means better throughput, load balancing and fairness.

In the proposed algorithm, central algorithm first checks if there is a new association request from a station. If there is a new request, algorithm increases its request count by 1 to prevent hidden node effect. Then algorithm gathers MAC layer information and RTCP periodic frames to calculate channel utilization rate and R values of VoIP flows. RTCP feedback can be easily acquired from RTCP sender and receiver reports [13]. The proposed algorithm uses two one-second fast feedbacks. Our algorithm maintains a multi-dimensional control array that contains caller ID, \( T_{delay} \), \( Loss \), \( R_i \), \( R_j \), \( R_{mean} \) values to assist rapid computations and responses. After calculations, algorithm defines its \( R_i \), \( R_{new \_old} \) and \( R_{new \_new} \) values and responds this additional information with beacon frames.

Up until now, we have addressed energy-efficient wireless communication for mobile-side. In order to increase overall
energy efficiency, we will now discuss AP switching on/off procedure. Since dense deployment of APs, which is essential to handle the ever-growing demand of performance and coverage, has been causing to the rise of power consumption, an efficient solution must reduce overall energy consumption of both APs and smart devices. In this context, each channel is investigated by APs, in terms of channel utilization, signal quality, probability of collision and deployed traffic types, making use of local and IEEE 802.21-based management frames. With the assist of these messages, APs inform the stations that are associated with themselves to maintain their connection or to handover to another network.

In this context, APs shares their channel utilization ratios (through CBTs) and their locations (through IEEE 802.21 MIIS). If an AP has less than a pre-defined (that is set as 3 users) affiliations, and if it also has at least one neighboring AP that has not highly loaded (that is set as higher than %70 of its capability), then the AP informs its associated stations to handover to a particular AP. If more than one AP is available, then the AP selects different APs for stations to associate by considering load balancing and multi-rate WLAN environment. By doing so, whenever there are more than one APs in a vicinity and they are not highly loaded, one or more than one APs can be switched off and the users of these APs can be transferred to other APs in that vicinity. This way, energy efficiency will be further increased.

IV. SIMULATIONS

Performance of the proposed methods has been evaluated by widespread simulations using the OMNET simulator and a custom-made object-oriented event-driven simulator software written in C++. Some of the parameters used to calculate formulas and implement the IEEE 802.11 MAC layer are shown in Table 1 and Table 2. We implemented our own TCP/VoIP traffic generator and evaluation tool that creates realistic data and multimedia packet streams using the parameters in Table 1 and Table 2. During the simulations, TCP frames are implemented as saturated frames. Voice frames are implemented as unsaturated frames and queued in 20ms intervals. In order to reach saturation condition, offered load has been set greater than maximum achievable throughput [3].

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitting state</td>
<td>1.3</td>
<td>W</td>
</tr>
<tr>
<td>Idle state</td>
<td>0.74</td>
<td>W</td>
</tr>
<tr>
<td>Receiving state</td>
<td>0.9</td>
<td>W</td>
</tr>
<tr>
<td>MinChTime</td>
<td>30</td>
<td>ms</td>
</tr>
<tr>
<td>MaxChTime</td>
<td>50</td>
<td>ms</td>
</tr>
<tr>
<td>ChSwitching</td>
<td>2</td>
<td>ms</td>
</tr>
<tr>
<td>Slot time</td>
<td>20</td>
<td>μs</td>
</tr>
<tr>
<td>Bit rate</td>
<td>11</td>
<td>Mbps</td>
</tr>
</tbody>
</table>

Table 1. Timing unit and values for IEEE 802.11b

<table>
<thead>
<tr>
<th>Name</th>
<th>Length (bits)</th>
<th>Bit rate (Mbps)</th>
<th>Time (μs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIFS</td>
<td>50</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td>Preamble</td>
<td>192</td>
<td>1</td>
<td>192</td>
</tr>
<tr>
<td>Header</td>
<td>240</td>
<td>11</td>
<td>21.81</td>
</tr>
<tr>
<td>Data (TCP)</td>
<td>8000</td>
<td>11</td>
<td>727.27</td>
</tr>
<tr>
<td>Voice (UDP)</td>
<td>1280</td>
<td>11</td>
<td>116.36</td>
</tr>
<tr>
<td>SIFS</td>
<td>10</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>ACK</td>
<td>112</td>
<td>2</td>
<td>56</td>
</tr>
</tbody>
</table>

Table 2. IEEE 802.11b parameter values used at simulations

Fig. 3 shows simulation topology. It is a static environment that is composed of stations (TCP and VoIP stations) and APs connected to a wired network. The number of stations, APs and channels are varied depending on scenario requirements.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3 APs</td>
<td>1120 ms</td>
<td>380 ms</td>
<td>54 ms</td>
</tr>
<tr>
<td>6 APs</td>
<td>1124 ms</td>
<td>423 ms</td>
<td>102 ms</td>
</tr>
<tr>
<td>11 APs</td>
<td>1122 ms</td>
<td>516 ms</td>
<td>198 ms</td>
</tr>
</tbody>
</table>

Table 3. Channel Sc. time of a station for various scanning schemes

Table 3 demonstrates comparison of passive, active and proposed IEEE 802.21-aided channel scanning schemes in terms of the total interval spent for the scanning process. As it is seen on Table 3, regardless of the total number of APs in a vicinity, our proposed scheme lets mobile devices perform channel scanning in much less time compared to both passive and active channel scanning methods. It is because proposed channel scanning scheme is mainly based on unicast channel scanning, which means stations scan only the channels informed by the 802.21 MIIS protocol. Due to reduced channel scanning intervals, proposed scheme achieves faster and more energy-efficient handover operation.

In order to evaluate the impact of the proposed scheme on fairness, we set different RSSI values for various APs. In that case, when the proposed algorithm was off, stations generally associated to the AP which has the highest RSSI value. When the proposed algorithm was on, stations associated to the APs were balanced due to the proposed algorithm checks all of R values, load balancing, hidden nodes and RSSI values. Therefore, the proposed method also provides desired fairness.

Throughout the simulations, we also evaluated the impact of minimum number of AP deployment on the power consumption, throughput, delay and jitter. In this context, we initiated an environment that has 6 APs, each of which has one TCP and one UDP station. When the proposed algorithm was off, 6 APs maintained their communications. However, when the proposed algorithm was on, each channel was investigated in terms of channel utilization, signal quality, probability of collision and deployed traffic types. Afterwards, the proposed algorithm informed 8 of these 12 stations to handover. This way, only two of six APs maintained their operations. Other four APs were switched off for the energy efficiency. In this context, Table 4 shows the comparison of power consumption, throughput, delay, jitter and number of active APs when the proposed algorithm is on and off.

![Figure 3. IEEE 802.11 network communication scenario](image-url)
Table 4. Comparison of power consumption, throughput, delay, jitter and number of active APs when the proposed algorithm is on and off

As it is seen from Table 4, the proposed scheme increases the energy efficiency dramatically by switching some of the APs off. However, since the remaining APs have denser channel utilization, average throughput is slightly decreased due to increased probability of collision. Besides, delay and jitter are increased due to frequent contention compared to the scenario of the "proposed algorithm is off".

V. CONCLUSIONS

In order to reduce the overall energy consumption of both Access Points and smart devices, this paper proposes an energy-aware Access Point switching procedure for smart mobile devices. In the proposed method, each channel is investigated, in terms of channel utilization, signal quality, probability of collision and deployed traffic types, making use of local and IEEE 802.11-based management frames. With the help of reputation, historical and context-aware computations, Access Points inform the stations that are associated with themselves to maintain their connection or to handover to another network.

The aim of the proposed scheme is to maintain desired Quality of Service with minimum number of operating Access Points and optimal energy consumption. In this context, widespread simulations have been executed to validate the efficiency of the proposed method. The results demonstrate that the proposed method dramatically increases overall throughput and reduces power consumption of stations over IEEE 802.11 WLANs.

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REFERENCES

Clustering of Mitochondrial D-loop Sequences Using Similarity Matrix, PCA and K-means Algorithm

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Abstract—In this study, mitochondrial displacement-loop (D-loop) sequences isolated from different hominid species are clustered using similarity matrix, Principal Component Analysis (PCA) and K-means algorithm. Firstly, the mitochondrial D-loop sequence data are retrieved from the GenBank database and copied into MATLAB. Pairwise distances are computed using p-distance and Jukes-Cantor methods. A phylogenetic tree is created and then a similarity matrix is generated according to the pairwise distances. Furthermore, the clustering is performed using only K-means algorithm. After that PCA and K-means are used together in order to cluster mitochondrial D-loop sequences.

Keywords—clustering; p-distance; PCA; Jukes-Cantor; k-means algorithm; similarity matrix.

I. INTRODUCTION

Mitochondrial DNA (mtDNA) sequences of mammals evolve more rapidly than nuclear DNA sequences [1], [2]. This fast rate of evolution generates more change between sequences. In order for research of closely related species and populations, this rate is a benefit [1], [3]. In animal mtDNA, there are four principal kinds for sequence changes. These are sequence rearrangements, additions, deletions and nucleotide substitutions [4], [5]. Nucleotide substitutions are the most important principal for the derivation of phylogenetic relationships [4], [6]. The fastest evolving part of the mitochondrial genome is the mitochondrial control region (Displacement or D-loop) [4], [7]–[9].

Principal Component Analysis (PCA) is a classical feature extraction and data representation method [10], [11]. In addition, it can be used to reduce the dimension of similarity matrix generated according to the pairwise distances and simplify the mitochondrial D-loop sequence data structure. The main features of the mitochondrial D-loop sequences can be extracted using PCA by means of mapping high dimensional space data into low dimensional space.

In phylogenetic analysis, distance measure is a significant matter [12]. Using p-distance and Jukes-Cantor methods, pairwise distances are calculated. Jukes-Cantor method is the simplest nucleotide substitution model which estimates the evolutionary distance between two sequences. Besides, it is called one parameter model in the literature [13]. This model can be applied to nucleotide substitution in alphabet (A, C, G, T) [14].

In data mining, the field of clustering has received significant attention in recent years and has become one of the important parts of machine learning research. Clustering is the process of categorizing a finite number of objects into groups where all members have common properties. Data mining is the process of using clustering algorithms in order to analyse data for patterns and relationships. K-means clustering algorithm [15] is one of the most used and popular clustering algorithms [16]. Furthermore, K-means is a simple unsupervised learning algorithm used to solve well known clustering problems.

The rest of the paper is organized as follows. In section II, the methods used for clustering of mitochondrial D-loop sequences are explained. Section III investigates the results of the methods used in this study. Finally, conclusions being under study are summarized in section IV.

II. METHODS

In this paper, in order for clustering mitochondrial D-loop sequences isolated from different hominid species, similarity matrix, PCA and K-means algorithm are used. To calculate pairwise distances, p-distance and Jukes-Cantor methods are utilized. K-means algorithm is used alone and then it is utilized with PCA for clustering. Clustering of mitochondrial D-loop sequences using Jukes-Cantor method is shown in Fig. 1. As seen in the flowchart, firstly, the mitochondrial D-loop sequence data are retrieved from the GenBank database. Secondly, retrieved sequence data are copied into MATLAB. After that pairwise distances are calculated using Jukes-Cantor method and then a phylogenetic tree is created. A similarity matrix is generated according to the pairwise distances. In addition, a dendrogram is drawn. Clustering is performed using K-means algorithm. Finally, K-means algorithm is used after applying PCA.

Clustering of mitochondrial D-loop sequences using p-distance method is shown in Fig. 2. As seen in the flowchart, unlike the first method, pairwise distances are calculated using p-distance method. Following steps are performed in the same manner.
In this work, 5 hominid species are utilized to cluster mitochondrial D-loop sequences. These are European Human, Russian Neanderthal, German Neanderthal, Chimp Trogloides and Mountain Gorilla Rwanda. When retrieving sequence data from the GenBank database, the accession codes for the mitochondrial D-loop sequences isolated from these 5 species are used. These codes are X90314, AF254446, AF011222, AF176766 and AF089820, respectively.

III. RESULTS AND DISCUSSION

In this study, to cluster mitochondrial D-loop sequences isolated from different hominid species, K-means algorithm is used and then it is used with PCA. Jukes-Cantor and p-distance methods are utilized in order to compute pairwise distances. The applications used for clustering of mitochondrial D-loop sequences are implemented using MATLAB R2014a. Phylogenetic tree created using Jukes-Cantor method is shown in Fig. 3.

Creating the similarity matrix according to the pairwise distances and drawing the dendrogram (Jukes-Cantor method) are shown in Fig. 4. Converting the pairwise distances to square form (Jukes-Cantor method) is shown in Fig. 4. Clustering using K-means algorithm (Jukes-Cantor method) is shown in Fig. 5. Performing PCA on square form (Jukes-Cantor method) is shown in Fig. 6. Clustering using K-means algorithm after applying PCA (Jukes-Cantor method) is shown in Fig. 7. Clustering using K-means algorithm after applying PCA (Jukes-Cantor method) is shown in Fig. 8.
Fig. 4. Creating similarity matrix and drawing dendrogram (Jukes-Cantor).

Fig. 5. Converting pairwise distances to square form (Jukes-Cantor).

Fig. 6. Clustering using K-means algorithm (Jukes-Cantor).

Fig. 7. Performing PCA on square form (Jukes-Cantor).

Fig. 8. Clustering using K-means algorithm after applying PCA (Jukes-Cantor).

Phylogenetic tree created using p-distance method is shown in Fig. 9. Creating the similarity matrix according to the pairwise distances and drawing the dendrogram (p-distance method) are shown in Fig. 10. Converting the pairwise distances to square form (p-distance method) is shown in Fig. 11. Clustering using K-means algorithm (p-distance method) is shown in Fig. 12. Performing PCA on square form (p-distance method) is shown in Fig. 13. Clustering using K-means algorithm after applying PCA (p-distance method) is shown in Fig. 14.
Fig. 9. Phylogenetic tree (p-distance).

Fig. 10. Creating similarity matrix and drawing dendrogram (p-distance).

Fig. 11. Converting pairwise distances to square form (p-distance).

Fig. 12. Clustering using K-means algorithm (p-distance).

Fig. 13. Performing PCA on square form (p-distance).

Fig. 14. Clustering using K-means algorithm after applying PCA (p-distance).
As seen in Fig. 3–Fig. 14, clustering of mitochondrial D-loop sequences isolated from different hominin species is successfully performed using similarity matrix, PCA and K-means algorithm. It is observed that both Jukes-Cantor and p-distance methods are practical for computing pairwise distances.

IV. CONCLUSION

In recent years, clustering has become a significant research topic in the area of machine learning. In this paper, when clustering mitochondrial D-loop sequences isolated from different homininid species, similarity matrix, PCA and K-means algorithm are used. First of all, K-means algorithm is used alone and then it is utilized with PCA in order for extracting features of the pairwise distances located in the similarity matrix. Besides, pairwise distances are calculated using Jukes-Cantor and p-distance methods. According to the study results, it is seen that the mitochondrial D-loop sequences are successfully clustered using similarity matrix, PCA and K-means algorithm.

REFERENCES

Texture Segmentation Based on Gabor Filters and Neutrosophic Graph Cut

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Abstract—Image segmentation is the first step of image processing and image analysis. Texture segmentation is a challenging task in image segmentation applications. Neutrosophy has a natural ability to handle the indeterminate information. In this work, we investigate the texture image segmentation based on Gabor filters (GFs) and neutrosophic graph cut (NGC). We proposed an image segmentation approach, which applies GFs to gray-level images to extract image features matrix, and it segments them into regions. First, color images are transformed to gray level images as input images. Then, input parameters of GFs are adjusted, and GFs are performed on the input images to extract features. The NGC is employed for classification of input images. Finally, experiments are conducted on various natural images to evaluate the approach. Experimental results show that the proposed approach achieves desired performance of texture segmentation. However, it cannot segment the texture-free images as well as texture images. In future works, we will try to segment both texture images and texture-free images at the same time.

Keywords—Image segmentation, texture segmentation, Gabor filters, Neutrosophic Graph Cut.

I. INTRODUCTION

The goal of the image segmentation considered as dividing an input image into several sub-images. To do this, some predefined criterions should be accepted where the sub-images are disjoint, homogeneous and meaningful. Many researchers have been working on image segmentation, and a variety of works have been published [1]. Texture segmentation is a challenging and important task in image segmentation applications. For the texture feature extraction, there exist various texture descriptors such as gray level co-occurrence matrix, Gabor filters (GFs) and Markov random fields [2]. GFs have been successfully applied to many image applications such as texture segmentation [3–5], document analysis [6], edge detection [7], retina identification [8], fingerprint processing [9], image coding [10], and image representation [11].

Graph based methods are important for image segmentation applications [12]. A graph $G$ can be defined as $G = (V, E)$ where $V$ and $E$ are a set of vertices and edges, respectively. On an image, vertices can be either pixels or regions, and edges connect the neighbouring vertices [13]. A weight, which is a non-negative measure of dissimilarity, is associated with each edge based on some property of the pixels that it connects. Normalized-cut, Minimal-cut and Mean-Cut can be seen in some of popular graph cut methods [14–16]. Neutrosophic set (NS) was proposed as an extension of fuzzy set [17]. In NS theory, a member of a set has a degree of truth, a falsity degree and an indeterminacy degree [18]. Therefore, it has an ability to deal with the indeterminacy information, and has attracted much attention almost in all engineering communities and subsequently a great number of works have been studied [19], [20].

In this paper, we propose a texture image segmentation algorithm which uses GFs, NS and graph cut method. Firstly, various GFs are considered which constructs a texture feature volume. Constructed volume is then projected into 2d by using principal component analysis (PCA). The projected feature image is transformed into NS domain and indeterminacy degree is calculated accordingly. Then an indeterminacy filter is constructed using the indeterminacy value on feature image which is defined by combining the spatial information and global texture feature information. The indeterminacy filter is employed to remove the indeterminacy in the intensity and spatial information respectively. A graph is defined on the image and the weight for each pixel is represented using the value after indeterminacy filtering, and the energy function is also redefined using the neutrosophic value. Finally, the segmentation results are obtained using a maximum-flow algorithm on the graph.

The organisation of the paper is as following; in Section 2 we give the methodology of the proposed method. In Section 3, some experimental works are conducted. Finally, we concluded the paper in Section 4.

II. METHODOLOGY

Briefly speaking, the proposed approach composed of 3 main building blocks. Extracting texture features from input image by using GFs is the first building block. This block constructs a texture feature volume according to the number of considered GFs. The second block employs the NS and calculates the indeterminacy degree accordingly. Then an indeterminacy filter is constructed using the indeterminacy value on feature image which is defined by combining the
spatial information and global texture feature information. This filter aims to remove the indeterminacy in the texture feature and spatial information respectively. Finally, a graph is defined on the image and the weight for each pixel is represented using the value after indeterminacy filtering, and the energy function is also redefined using the neutrosophic value. Finally, the segmentation results are obtained using a maximum-flow algorithm on the graph. The flowchart of the approach is illustrated in Fig. 1.

The GFs theory was described in Jain and Farrokhnia [21]. GFs should be in array form and it is designed with different orientations and frequencies. The step of orientation angle can be 30, 45, etc. degrees and orientations are shown as below:

$$Orients = [0, a, 2 \times a, \cdots, 180 - a]$$  \hspace{1cm} (1)

where \(a\) is the step of orientation angle. Wavelengths have values in increasing powers of two start from minimum wavelength to maximum wavelength.

$$w_{\text{min}} = \frac{4}{\sqrt{2}}$$  \hspace{1cm} (2)

$$w_{\text{max}} = \sqrt{im_{\text{rows}}^2 + im_{\text{cols}}^2}$$  \hspace{1cm} (3)

where \(w_{\text{min}}\) is the minimum value of wavelength, \(w_{\text{max}}\) is the maximum value of wavelength. \(im_{\text{rows}}\) and \(im_{\text{cols}}\) are the size of rows and columns of the input image.

$$n = \left\lfloor \log \left( \frac{w_{\text{max}}}{w_{\text{min}}} \right) \right\rfloor$$  \hspace{1cm} (4)

$$Waves = [2^0, 2^1, 2^2, \cdots, 2^{(n-2)}] \times w_{\text{min}}$$  \hspace{1cm} (5)

The set of orientations and wavelengths are taken from [21]. Working GFs mean working with Gabor magnitude response of each filter. The size of the magnitude response is:

$$Orients_{\text{len}} \times Waves_{\text{len}}$$  \hspace{1cm} (6)

where \(Orients_{\text{len}}\) is the length of array of orientation \(Orients\) in Equation (1), and \(Waves_{\text{len}}\) is the length of array of wavelength \(Waves\) in Equation (5).

When using Gabor magnitude responses as features, some post-processing is required. Feature smoothing and normalization is applied as post-processing. In smoothing process, the Gaussian process and normalization is applied in order to get zero mean and unit variance. Smoothing is important because some local variations in each Gabor response are not suitable for the segmentation and they can be soften by using a low-pass filtering. In addition, spatial \(x\) and \(y\) axis properties of each pixel are added to the features matrix. Spatial location information improves the segmentation process to prefer groupings that are close together spatially. After the post-processing, we apply the PCA in order to reduce dimension size of the feature vector. PCA, is a procedure which uses an orthogonal transformation [22]. The transformation is carried out with the first principle component.

After PCA, the reduced feature matrix is fed into the NS domain. A neutrosophic image \(I_{\text{NS}}\) is interpreted using three subsets \(T_s\), \(I_s\) and \(F_s\). Based on the texture feature value and local spatial information, the true membership and indeterminacy membership are used to describe the indeterminacy among local neighbourhood as:

$$T_s(x, y) = \frac{g(x, y) - g_{\text{min}}}{g_{\text{max}} - g_{\text{min}}}$$  \hspace{1cm} (7)

$$I_s(x, y) = \frac{Gd(x, y) - Gd_{\text{min}}}{Gd_{\text{max}} - Gd_{\text{min}}}$$  \hspace{1cm} (8)

where \(g(x, y)\) and \(Gd(x, y)\) are the gray scale texture feature value and gradient values at the pixel of \((x, y)\) on the image, respectively. The algorithm also computes the neutrosophic membership values based on the global texture feature value distribution which considers the indeterminacy on texture feature value between different groups. To this end, NCM is used to obtain the indeterminacy values between different groups on texture feature value to be segmented [23]. Before calculation of the global texture feature value based NS memberships, the obtained local \(I_{\text{NS}}\) is filtered by indeterminate filter based on \(I_s\). After, constructing \(I_{\text{NS}}\), an energy function for graph model is determined and the \(I_{\text{NS}}\) is partitioned using maximum flow algorithm [24].

The algorithm of the proposed method is as following:

Step 1: Compute the GFs of input texture;

Step 2: Smoothing and normalization Gabor responses;

Step 3: Dimensionality reduction with PCA;

Step 4: Compute the local neutrosophic value \(T_s\) and \(I_s\);

Step 5: Filter \(T_s\) using indeterminate filter based on \(I_s\);

Step 6: Employ NCM algorithm on the filtered \(T_s\) subset to calculate \(T_n\) and \(I_n\);

Step 7: Filter \(T_n\) using indeterminate filter based on \(I_n\);

Step 8: Define the energy function based on the \(T'_n\) value;
Step 9: Partition the image using the maximum flow algorithm.

III. EXPERIMENTS

Experiments are conducted on various natural images from Berkeley Segmentation Dataset (BSD) to evaluate the approach. Four images are selected randomly to show the performance of the method. These images are “Cheetah”, “Lady”, “Plane” and “Zebra”, respectively. As shown in Fig. 2, each of figure which includes these images has four types of images. First image is original gray-level and second image is after Gabor filtered and PCA image. Third image is segmentation result of NGC of the first. Fourth image is border result of NGC of the first.

Fig. 2. Top-left: Cheetah image, top-right: result image after GF and PCA, bottom-left: segmentation of NGC, bottom-right: border of segmentation.

GFs are applied to the input images to extract texture features. To use GFs as features, the orientations and the wavelengths should be selected and calculated. We consider the “Cheetah” image in Fig. 2 to examine the process of feature extraction. As seen in Fig. 2, the input image is a gray-level image. Its size is 321×481 pixels. Minimum wavelength is mentioned at upper section and it is 2.8284. Maximum wavelength is calculated via size of the input image. Maximum wavelength is $\sqrt{321^2 + 481^2} = 578.2750$. The wavelengths that send to Gabor magnitude as input parameter, start in increasing powers of two from minimum wavelength up to maximum wavelength. For the “Cheetah” image, the wavelengths have six values: {2.8284, 5.6569, 11.3137, 22.6274, 45.2548 and 90.5097}.

Orientation angle called theta begins with 0 degree and continues with 45 degrees increase thus it has four values for the “Cheetah” image: {0, 45, 90 and 135}.

The related illustrations are given in Figs 2-5. As can be seen in these figures, the proposed method produced reasonable segmentation results. The objects in the input images are well segmented from the background. However, the boundaries of the object are rough and need further post-processing. Especially, for woman image, the head of the woman is not correctly segmented. In addition, several over-segmentations are clear.

Fig. 3. Top-left: Lady image, top-right: result image after GF and PCA, bottom-left: segmentation of NGC, bottom-right: border of segmentation.

Fig. 4. Top-left: Plane image, top-right: result image after GF and PCA, bottom-left: segmentation of NGC, bottom-right: border of segmentation.

IV. CONCLUSIONS

This paper presents a texture image segmentation using GFs and NGC method. Before the image is described in NS domain, GFs are applied on the image to extract texture features. The experimental results show that the NGC method can segment the images properly and the proposed approach achieves desired performance of texture segmentation. The disadvantage of the proposed method is rough segmentation. To overcome this disadvantage, in the future works, a boundary preserving filtering method will be adopted.

REFERENCES

Fig. 5. Top-left: Zebra image, top-right: result image after GF and PCA, bottom-left: segmentation of NGC, bottom-right: border of segmentation.


Internet of Things: A Survey

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Abstract—Internet of Things (IoT) is a global infrastructure worldwide which links objects and enables data generation and sharing of this data. IoT is considered as one of the most important areas of future technology and gets attention considerably by researchers and practitioners in recent years. Applications presented by IoT makes possible a large number of developments, but very few can be used currently. With rapid advances in this system technology, successful implementations will continue to emerge to improve the quality of life in many areas. In this study, IoT is examined in general terms and its applications, advantages and disadvantages are reviewed.

Keywords—Internet of Things, RFID (radio frequency identification), Sensor, Smart objects.

I. INTRODUCTION

Internet has made a significant impact on the economy and society bringing exceptional network infrastructure and communication. It has been more persistent with the advent of the low cost wireless connection. With emerging technologies, billions of people are connected to the Internet via portable computers or mobile devices. After this stage, the expected big step is that interconnected computers exchange information with interconnected objects.

IoT is considered as a part of the Internet of the future and will comprise billions of intelligent communicating ‘things’. You can think of all the things / objects as from cars to books, from electrical appliances to foods, from refrigerators to water heaters, from intelligent buildings to shoes that are connected with each other will be a development waiting for us in the future. Products previously consisting of only mechanical and electrical components will return to hardware, sensors, electronics and complex devices which are interconnected in a variety of formats via the internet and even some platforms [1]-[4].

It is becoming more apparent, we stand on the threshold of new computer applications era that will radically affect our lives. But the oncoming wave of technological revolution will affect us more from all directions; it seems that our near future will be filled with small processors which communicate with each other simultaneously and these will be integrated into the majority of everyday objects when their small sizes and low costs are considered [5].

Internet of Things has emerged as new platforms in the Information and Communication Technologies revolution of the 21st century. This platform is used to provide (on demand) services and resources in different domains including education, commerce, healthcare, public sector and various governmental organizations [6]. Internet of things is a new world for connecting every object of the real world with the virtual space in the computer world. IoT is a type of network that links physical objects that surround us with the virtual world to perform information exchange [7].

When the literature is viewed, many of identification of internet of thing are seen;

The Internet of Things is the connection – via the internet – of objects from the physical world that are equipped with sensors, actuators and communication technology [8].

The Internet of Things is a novel paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as Radio-Frequency Identification tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [9].

The Internet of things is a things connected network, where things are wirelessly connected via smart sensors; IoT is able to interact without human intervention [4].

The internet of things is a network of objects equipped with radio frequency identification chips and similar technologies so that the objects could communicate and interact with each other [10].

The internet of things is a common worldwide network which in a unique way addressable things/objects created by them and the objects in the network are in contact each other with a specific protocol [2].

The impact of the IoT has influence on many areas in a short time. Especially, ability of IoT which adapts to any environment, in any conditions without restriction of place, time and object has made it popular [11]. IoT is currently going through a phase of rapid growth. Gartner, Inc. forecasts that 6.4 billion connected things will be in use worldwide in 2016, 30 percent more from 2015, and will reach 20.8 billion by 2020. In 2016, 5.5 million new things will get connected every day. Gartner estimates that the Internet of Things will support total services spending of $235 billion in 2016, 22 percent more from 2015. Services are dominated by the professional category (in which businesses contract with external providers in order to design, install and operate IoT systems), however connectivity services (through communications service providers) and consumer services will grow at a faster pace [12]. The evolution of IoT can be illustrated by several phases as shown in Fig. 1 [4].
In 1991, academics at the University of Cambridge share
the one coffee pot where they work. Researchers whose offices
on the lower floors of the building become uncomfortable to
find the coffee pot empty and they design a system which
captures three images of coffee pot in a minute and transfer to
their computer. After writing of protocols, image capture
software and with a video camera, each researcher could
see the quantity of coffee in the coffee pot on the screen in real
time and online. By 1993, this application moved web has
been watched millions of times a day and it was terminated
due to department move to another building in 2001. This
coffee pot was the first proof and example of the existence
of "Internet of Things"[2].

The term Internet of Things was firstly coined by Kevin
Ashton in 1999 in a presentation prepared for Procter &
Gamble Company. He sorted and proposed the benefits of
application of RFID technology in the supply chain and the
cost became popular through the Auto-ID Centre at MIT
[13]-[15]. Then, scientists and researchers have gradually
accepted the concept of IoT. The formal IoT concept was
given by International Telecommunications Union (ITU) in
2005 ITU released the report on the Internet, titled “The
Internet of Things”. The academic milestones in the brief
history of IoT are illustrated in Fig. 2 [10], [16].

Atzori et al. [9] reported different visions of Internet of
Things paradigm and surveyed the most important aspects of
the IoT. Kiritsis [17] studied on intelligent products in the era
of IoT.

Gu and Liu adapted Internet of Things applications to
information management in the reverse logistics in 2013.
Ondemir and Gupta proposed a mixed integer programming
model used IoT for minimizing remanufacturing, disassembly,
recycling, disposal and storage plans in a demand driven
environment in 2014 [13].

Tsai et al. [18] reviewed studies on basic concepts,
arichitectures, discussions and comparisons of IoT and Future
Internet of Things (FliOTr) and gived open issues and
challenges of IoT and FlOTr. Then they presented an intelligent
data management framework for the FliOTr. Also similar
review studies are found in [1], [4], [10], [15], [19], [20]. Lee
and Lee [21] presented essential IoT technologies and
identified three categories of IoT applications (monitoring and
control, big data and business analytics, information sharing
and collaboration). They also presented investment
opportunities and evaluation and discussed challenges of IoT.
Shrouf and Miragliotta [22] presented a framework for IoT-
based energy management to support the integration of
gathered energy data into a company's information technology
platforms and contributed to the understanding of energy-
efficient production management practices that are enhanced
by the Internet of Things technology.
Dijkman et al. [8] presented a business model framework for Internet of Things applications. Sicari et al. [23] presented the main research challenges and the existing solutions in the field of IoT security. Tao et al. [16] introduced the concept, characteristics, applications of IoT and analyzed energy consumption in product life cycle. Then they summarized the existing applications of IoT in product life-cycle energy management and analyzed the potential applications and challenges of IoT in product life-cycle energy management. Verdouw et al. [24] analyzed concept of virtual food supply chains with Internet of Things and proposed an architecture to implement enabling information systems. Then they verified the proposed architecture with a case study of a fish supply chain. Fang et al. [25] presented an integrated three-stage model based on IoT technology for the optimization of procurement, production and product recovery, pricing and strategy of return acquisition and proposed a novel particle swarm optimization algorithm based on two heuristic methods to solve the problem.

Aktaş et al. [3] suggested a system based IOT which allows viewing physiological data received from hospitalized babies in infant intensive care unit targeted realization within the scope of this technology both from the hospital environment and outside the hospital environment, referring to the IoT technology applications in the health field.

The aim of this study is to examine the concept of "Internet of Things" widely used in recent years and to determine the existing situation of IoT. Thus, it was strived to obtain more information about IoT that is a technology revolution. Following the introduction, the main components of IoT described in second section and current applications of IoT were discussed in the third section. Then the potential difficulties beside the opportunities of IoT were mentioned in the fourth section. And study is terminated with conclusion section.

II. FUNCTIONAL VIEW OF IOT

Internet of Things is comprised of three main components. These are;
1. Assets that represent portion of "Objects" of Internet of Things concept,
2. Networks that link these objects,
3. Computer systems that use data from the object [26].

Fig. 3 Three main components of Internet of Things [26]

Internet of Things is an interplay of smart objects and smart communication networks and include own system storage, computing, visualization and interpretation tools for data analytics [15], [22].

When objects equipped with sensors and electronic circuits, they begin to acquire properties “thinking”, "feeling" and "speaking". Thus, they have access the ability to update their own status information by contacting us [2].

Smart objects embedded device of IoT;
1. It has a unique identity.
2. It has the ability to communicate effectively with environment.
3. It has obtained and storage capability data related itself.
4. It deploys a language to show properties, production demands etc.
5. It has capable of making decisions about its own fate [27].

They can communicate and interact either among themselves, building networks of interconnected objects, or with end-users or other entities in the network [20].

Think of a cup that can access the Internet. It is able to detect what is the liquid put into it. Not only as a species; also in terms of the content-forming composition. This information can be transferred to a desired application or environment on the internet. Thus, you can examine the knowledge of fluid you drink throughout the day, for example through an application on your smart phone, at the end of the day. Cups, on top of that, can keep statistics. It can map your liquid consumption by determining what you drank in what time of day. It can suggest that you drink coffee when your coffee time. Even it can order instead of you at a nearby coffee shop [28].

Actualization of IoT into the real world is possible by the integration of several effective technologies [9]. These technologies are provided below.

A. Radio Frequency Identification (RFID)

Radio frequency identification allows automatic identification and data capture using radio waves, a tag and reader. RFID is key component of IoT system and also the newest identification technique among all IoT technologies. RFID as a technology for IoT is used to identify and track items. If objects (even people or animals) are equipped by identifiers, they can be managed and registered automatically; therefore, it is then possible to track the full transportation way of these objects [9], [14], [21].

Passive RFID are not battery-powered, therefore they use the power of the reader’s interrogation signal to communicate. Active RFID tags contain sensors and have their own battery supply and can communicate. Although passive RFID tags are sufficient for tracking, active RFID tags with embedded sensors can provide a lot more information about the usage/condition of objects. Sensor detects the changes in the value of various measures such as temperature, pressure, vibration and humidity and converts the signal to be recorded. RFID tag containing static information such as serial number, model, bill of materials, production and delivery date of the product is connected to the product and can be updated after
the operations such as each maintenance, improvement. Dynamic information such as environmental conditions occurring during use of the product, working time and frequency of the product is recorded with the help of sensors [13], [15], [21]. Fig. 4 shows building blocks of IoT.

![Fig. 4 Internet of Things](image)

**B. Wireless Sensor Networks (WSN)**

Wireless network which contains vehicles working independently and use sensors to monitor a cooperative manner physical or environmental conditions such as temperature, humidity, light, sound, pressure, pollution, soil composition, noise level, vibration, object moves in different places is called "wireless sensor network". Sensor networks play a crucial role in the IoT. Typical Wireless Sensor Networks consist of hundreds or even thousands of sensor nodes that connect via a wireless environment and exchange information with each other. Improvements in hardware and wireless system have enabled the production of low cost, low power consumption, multifunctional miniature sensing devices. Ad hoc networks can be created with the help of hundreds-thousands of these devices. For example, these devices create a wireless ad hoc network distributing over a wide geography. These sensors that distributed and formed the network generate a sensing network system by cooperating. A sensor network allows to access information easily at anytime, anywhere. It performs this function by collecting, processing, analysing and spreading data. [30].

The integration of WSN and RFID empowers IoT and makes possible to develop IoT applications [4].

**C. Middleware**

Middleware is a software layer between the technological and the application levels. Middleware architectures proposed in the last years for the IoT [9]. The complex distributed platform of the IoT requires simplifying the development of new applications and services, so use of middleware is an ideal option with IoT application development. More importantly, a centralized infrastructure to support storage and analytics is required. Storage and calculating tools for data analytics are included in middleware. The data have to be stored and used intelligently for smart monitoring and actuation. Many IoT applications require massive data storage, huge processing speed to enable real time decision making, and high-speed broadband networks to stream data. As of 2012, Cloud based storage solutions are becoming increasingly popular. Cloud computing provides an ideal back-end solution for handling huge data streams and processing them for the numerous number of IoT devices and humans in real time [1], [15], [21].

**D. Presentation**

Presentation is related to visualization and interpretation tools. These tools can be accessed on any platform and can be designed for a large variety of applications. Presentation allowed the interaction of the user with the object in real time anywhere, anytime is important for IoT systems [1], [15]. For example, IoT-enabled home appliances and devices can be monitored and controlled outside the user’s home through a computer, tablet, or smart phone due to presentations function of IoT [21].

**III. APPLICATIONS OF IOT**

Internet of Things that is called a new industrial revolution in the whole world finds itself in many fields of application possibilities. In recent years, it has attracted great attention and is used in various fields by researchers and practitioners worldwide.

Opportunities offered by the IoT make possible the development of a large number of applications [9]. IoT have been widely used in Transportation, Smart Home, Smart Factory, Smart City, Supply chain, Lifestyle Security, Retail, Agriculture, Emergency, Health care, Culture and tourism, User interaction, Environment and Energy, Library services, Food and restaurant industry and many other areas (Fig. 5). In the following subsections, a few typical applications examples are given.

**A. Smart environments**

A smart environment can be an office, home, industrial plant, city or any environment and it make our life more comfortable due to the intelligence of included objects [9].

Home appliances such as televisions, washing machines, refrigerators, air conditioners and many other devices can be controlled very efficiently, so, this smart system provide better home and energy management [1].

For example, rooms heating can be adjusted to our preferences and to the weather; lighting can change according to the time of the day; dangerous incidents can be prevented with suitable monitoring and alarm systems; and energy can be saved by automatically switching off the electrical equipments when not needed [9]. For communication between people and the smart environment a smart phone can be used. So far, there are several applications available for Apple iOS, Google Android and Windows Phone operating systems that measure various parameters [15].
B. Transportation and logistics

IoT really plays an increasingly important role in transportation and logistics. Intelligent transport systems that count vehicles on the road, calculate the travel time, determine the pits and calculate the using time of the parking place can be established with the help of sensors. Moreover, it is possible to realize better traffic management with data obtained from such a system [31].

Internet of Things means that the rich data and deep intelligence for all parties in the network from the manufacturer to the end user for supply chain. Real-time monitoring and object move tracking from an origin to a destination will be guaranteed with objects attached RFID tags or sensors so that transportation and logistics can be more efficient and accurate during the entire supply chain [16].

Some important benefits of internet of things related to the supply chain:
- The storage can be monitored in real time. Both the number of stored product and the costs can be reduced by eliminating redundant production and storage. In addition, turnaround time can be shortened; needless handling, loss and theft can be prevented.
- Prevents alteration of information enabling to store all kinds of information (Eg. Production date, expiry date, warranty period, after sales details) in objects and share by supply chain stakeholders in real-time.
- Business process optimization; smart objects used in the framework of business processes accelerate and facilitate the detection of potential problems and support the detection of a possible process optimization [32].

C. Health care

Healthcare is an important application area of IoT and in this sector, a number of applications containing IoT technologies can be found. Internet of Things offers a variety of solutions at the stage of take measures, monitories and diagnose depending on the health status. Devices can help individuals to control their own health status such as weight, body mass, sleep patterns and daily activity rate [31].

This systems include identification for reduce incidents harmful to patients such as wrong drug/dose/time/procedure. Tracking for identify of a person or object in motion. Data collection and transfer for reducing form processing time and medical inventory management. Sensing for diagnose patient conditions [9].

Patients carry medical sensors to monitor parameters such as body temperature, blood pressure, breathing activity. All
the healthcare-related information is collected by these sensors and managed efficiently and it can be able to perform advanced remote monitoring and can be capable of rapid response actions when needed. For example, fall detection application can help elderly or disabled people live more independently [16], [20]. It can be foreseen that the IoT with intelligent medical sensors will enhance the quality of life significantly and prevent the occurrence of health problems.

On the other hand, the rapid development of mobile devices and health applications creates a huge market for the application of IoT. Individual mobile health applications have been developed to serve healthcare tasks such as the measurement of blood pressure or recording of blood glucose [4].

D. Security and Emergency

Internet of Things can enhance security and help government in the emergencies. Devices that transfer information between each other quickly can be built in a condition of natural disasters or requires medical priority. Apart from that, ambient sensors can be used to monitor the presence of dangerous chemicals. Sensors monitoring the behaviour of people can be used to assess the presence of people acting in a suspicious way [20].

E. Agriculture

Internet of Things allows to establishment of smart fields that each step can be observed to increase agricultural production. The atmospheric, water, soil, and other information can be collected in real time and accurately with IoT technology to improve the efficiency and quality of agricultural production [16]. The smart irrigation systems provide ease about giving information about the condition of the soil and reducing water consumption with the aid of sensors. The system analyzes the data collected and realizes the irrigation process according to soil needs in the area where the irrigation system is installed. In addition, solutions based data offered by the Internet of things offers the option to be able to follow even the food which they eat to consumers in terms of food security [31].

Apart from these applications, many others may be envisaged many other applications that are define futuristic, because these base on some technologies that either is still coming or whose practice is still too complex[9].

IV. PROS AND CONS OF IOT

Internet of things feed on data in the continuous flow and composed of a variety of devices and millions of sensors is a technology that enables to facilitate our lives with many uses area and develop business processes. Data usability, continuous monitoring capability, time (money) savings are among the main advantages of the system. But, there are also challenges alongside opportunities that this system offers us. Although the success of IoT has confirmed the potentials, we have to confront with the challenges of IoT soon [18]. The disadvantages that are believed to be slowly eliminated result of the adoption of this technology;

A. Complexity

IoT is a very complex heterogeneous network included the connections among different networks through several communication technologies [4]. Data collected from sensors of IoT will become very large because of enormous amount of things connected internet. Current computer systems or sensors may not have enough storage to keep all this data [18]. The amount of data that will be occurred by billions of objects connected to this system will increase incredibly and this large data processing will become difficult and complex task.

B. Security and privacy

The system establishes on a huge of network system bring along the cyber security risks. Main security issues in IoT are illustrated in Fig. 6.

IoT will gather and store huge amount of personal information due to increase in connected devices. And so, this data is attractive to hackers and other cyber criminals [1]. There are many ways IoT system could be attacked disabling the network availability; pushing erroneous data into the network; accessing personal information; etc [15].

Although a number of projects have been developed for security and privacy protection, a reliable security protection mechanism for IoT is still in demand for data confidentiality, privacy, and trust [4]. This is the most important issue to prevent the use and become widespread of IoT. Therefore, valid security, privacy and trust models suitable for the IoT applications should be define and sensible solutions (such as intrusion prevention systems, firewalls) should be found in terms of technical to ensure customer privacy and security. Because, the run-up and acceptance of IOT technology will depend on the protection of users' privacy.

![Fig. 6 Security Challenges of IoT](image_url)
C. Convenience

Another concern for the Internet of Things is the problem of convenience. Since currently Internet of things is the initial phase of the idea and development, there are yet no convenience standards for labeling, monitoring equipment, providing data definition, capture and exchange, special software, end to end security and individual management etc. [10], [26], [33]. In recent years, a number of standardization activities focused tag-based technologies have been active and these standardization activities on the sensor and RFID [20].

V. CONCLUSIONS

Internet, indispensable of today, is highly effective in many areas such as education, business life, communication and daily life. But, traditional internet is not sufficient in capturing real-time data because it still depends on people. Internet of things is a technology that objects and creatures can transfer data connected to Internet without need for human-human and human-computer interaction [34]. Therefore, IoT is considered as part of the overall Internet of the future, which is likely to be dramatically different from the Internet we use today [9]. Given that humans advance and evolve by turning data into information, knowledge, and wisdom, IoT plays a very important role in the future emerging technology and it has the potential to change the world as we know it today for the better [1], [10].

If IoT that provides connection of any object, anyone, anytime and anywhere correctly applied, increase of things/objects that produce their data by themselves in real time will bring more reliable knowledge. Thus, the losses will be reduced, the waste will be prevented and after that costs will decrease. But unless required standards and rules of this system, the situations be encountered may blow innovativeness. For this, like all technological viewpoint innovations, the changes should be expected and accepted.

In conclusion, IoT represents the next evolution of the Internet and for a few years now, IoT has been developed dramatically and a great number of enabling technologies have been proposed. In this paper, some studies conducted up to this day were summarized mentioning the development of internet of things. Later, the main components of IoT described and current applications of IoT were given. Finally, the potential difficulties beside the opportunities of IoT were mentioned. It is expected that this survey will be useful for researchers and practitioners, helping them to understand enormous potential of Internet of Things and in addition this, to foresee the challenges of IoT which will be encountered.

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An Expert System for Boring Tools Used for Machining Holes

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Abstract—Boring is a finish operation that widely used to machine the holes on the mechanical parts in manufacturing industry. The Boring also is a method that is usually preferred to size holes that can meet the appropriate tolerance. There are many tools for boring process in the world wide. Generally, Boring tools were parted two groups that are milling and turning. The boring tools especially for milling were packed in many set that include head, bars, etc. Decision of using any set in these packed is not easy exercise. For this reason, selection suitable head, bars, cutting tools and cutting conditions need long preparation time and good expertise for boring process in milling. Because of the quality of holes is depended by determining these parameters rightly.

In this study, an expert system that is called BT_expert was developed for using the boring tools in milling. BT_expert was built up by using an expert system shell that is called Kappa PC. Kappa PC is preferred because of programming with C++. BT_expert has a friendly user interface that is designed visual objects. A lot of rules about 70 are written for BT_expert. The system asks a few simple questions to user about boring process. And, BT_expert can make a decision by using forward chaining mechanism. Finally, BT_expert system determines the boring bars, cutting tools and ideal cutting parameters automatically.

As a result, BT_expert system makes easy to select boring and cutting tools, and cutting parameters correctly in many set without any expert. And, the system decrease the long preparation time of boring process.

Keywords—Boring, Boring tools, Milling, Expert System, Kappa PC

I. INTRODUCTION

Nowadays, computers’ hardware and software use easily for many applications in many areas. For example, machining is a very important area that is widely used computers and programs. Computers and programs provide a lot of advantages, such as speed, accuracy, lower costs, etc. Generally, computer programs have an algorithm. So, solutions of these programs are not enough for all application. Because, an expert decision require for some application. In addition, many years need to be an expert of a person in a sector. For this reason, a lot of expert systems were developed on the world. Expert Systems (ES) have very special programs. These systems solve a problem according to rules obtained from the knowledge of the experts. In other word, the ES evaluate knowledge, the classical programs that have algorithm evaluate evident data. Thus, ES provide to use expertise at any time without an expert person.

ES is a technique used in artificial intelligence discipline. Moreover, there are a lot of techniques such as neural networks, genetic algorithm, fuzzy logic, image processing, in artificial intelligence discipline. Especially, ES [1], [2] and neural networks [3] well as various programs are used in the process sequence. Also, ES is an intelligence program that uncovers an expert thinking and behaviour for a specific area [4]. ES can calculate the data and make inferences something by using about information in the knowledge base. Thus, they provide fast and reliable solutions for special problems. ES is an interactive system for experts in many areas.

Expert systems were improved with different capabilities for many areas since computers were invented. Especially, these systems rapidly climbed high level in 20th century. However at present time, new expert systems have been implementing to solve problems and select optimal parameters (boring tools, material, cutting tools and cutting conditions) in machining industry in the world. Some studies carried out in this direction are summarized below.

Tan, et al. [1] have designed a selection of cutting tools of expert and have checked the accuracy of the system for CNC turning. An expert system called EXTOOL developed by D. Mookherjee and Bhattacharyya [2]. The program stated that the process for the customer’s choice of material and types for cutting lathes and milling enables automatic determination based on geometry. An expert system for the selection of cutting tools and turning conditions were developed by Arezoo et al. [5]. Sapuan, et al. [6] were developed a system of specialist material election for tools and components for ceramic matrix composite. Er and Dias [7] were improved an expert system engineering components, based on which the selection rule for the production of casting system. Kayir, et al. [8] were built up an expert system by using Leonardo shell program for selection optimal cutting tools and operation for drilling holes. Poyrazoglu, et al. [9] were implemented an expert program to choose right operation from non-traditional machining methods.

In this study, an expert system called BT_expert was developed for machining of various size holes. BT_expert selects the optimal boring tools that are commonly used for machining holes desired with geometrical tolerances. The system was built up with KAPPA-PC expert shell program. BT_expert system contains 4 modules. They are database module, reasoning (inference engine) module, user interface module and knowledge base module. BT_expert makes a decision for selecting an optimum boring cartridge, cutting
tool (insert type and radius), cutting parameters (cutting speed, feed rate). It has user interface that includes screen pages formed menus, buttons. User can input or change data on these pages. The system can be used easily by any man (engineer, worker, etc.). BT_expert reduces planning time and improves product quality because of choice right boring cartridge and the insert and cutting parameters for boring operations.

II. BORING TOOLS

Boring machining can be referred as one of the difficult process in machining. Boring process is widely performed on the lathe and milling machine tools. Boring process is process of completing finished final dimensions and tolerances by upsizing parts of which first bore is drilled. The machining process is performed as a finish work. After performing the boring process, additional boring operations cannot be performed on the hole. Hole is ready to use. Boring process is similar to the hole turning on the lathe, but in this process boring tool rotates not workpiece. Hole is machined by performing an eccentric movement of the boring tool.

In boring process a lot of boring tools are used. Boring tools exist in different sets that include a lot of parts in the market. In addition to different types of boring tools in the market, boring tools are classified according to specialties of hole which will be processed. (rough and finish etc.). Classified boring sets (Fig.1) are capable of machining specific diameter hole in specific circumstances. It is required that a boring cartridge is determined according to first hole and final hole shown at Fig.1.

One of the subjects which have to be considered is that diameter of the selected boring cartridge is not too smaller than the first bore of workpiece.

The other subject is that the length of the selected tool is not too longer than the hole’s length. In this study by looking L/D rate, the determination of boring cartridge is done. L shows deepness of the hole and D shows the diameter of the final hole. Programme offers a higher level boring cartridge when L/D rate is higher than 2.5. If this case is not paid attention in Boring tool that will be used, chatters are observed over the hole surface. Abele et al., in their study, placed a damping system to shaft of boring tool for preventing chatters [11].

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The other subject is that the length of the selected tool is not too longer than the hole’s length. In this study by looking L/D rate, the determination of boring cartridge is done. L shows deepness of the hole and D shows the diameter of the final hole. Programme offers a higher level boring cartridge when L/D rate is higher than 2.5. If this case is not paid attention in Boring tool that will be used, chatters are observed over the hole surface. Abele et al., in their study, placed a damping system to shaft of boring tool for preventing chatters [11].

II. BORING TOOLS

Boring machining can be referred as one of the difficult process in machining. Boring process is widely performed on the lathe and milling machine tools. Boring process is process of completing finished final dimensions and tolerances by upsizing parts of which first bore is drilled. The machining process is performed as a finish work. After performing the boring process, additional boring operations cannot be performed on the hole. Hole is ready to use. Boring process is similar to the hole turning on the lathe, but in this process boring tool rotates not workpiece. Hole is machined by performing an eccentric movement of the boring tool.

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One of the subjects which have to be considered is that diameter of the selected boring cartridge is not too smaller than the first bore of workpiece.
So, there are a lot of parameters correctly determined for successful operation in boring machining. Especially, boring tools, insert cutting tools and cutting parameters must be chosen correctly to get precision and desired tolerance. Mistakes made in their selection cause faults on machined holes and used tools. In a study, Rao et al. try to estimate the occurred vibration, the surface roughness and the tool wear during the machining hole on AISI 316 material by using artificial neural networks [10].

III. BT_EXPERT SYSTEM AND BORING TOOL SELECTION

KAPPA-PC expert shell program was used to develop a system that is called BT_expert system for holes machining. BT_expert system was designed for two main objects that are boring tools, cutting tools and cutting parameters. There are several factors for preference the KAPPA_PC shell program to develop BT_expert. KAPPA PC expert shell program is suitable program to improve any application in field of machining sector [12]. In addition, KAPPA-PC is an object oriented program. In KAPPA-PC program all objects are connected each other with a tree structure form (Fig. 3).

To get the best solution, about 72 rules were written in this study. Generally, structure of rules consists of “IF” and “THEN” words. The word of “IF” is used to determine the conditions. All conditions in rules are linked with “AND” words. The word of “THEN” leads to the conclusion. A sample rule written in the BT_expert is given at Fig. 4.

Moreover, name of the rules and task, and numbers of each task about 72 rules written in the BT_expert rule base are shown at Table 1.

Rules defined in the BT_expert rule base automatically associated with each other. For example the connection of Barasecimi 1 with other rules in the BT_expert rule base is shown at figure 5. Generally, two methods are used to evaluate rules for solution of any problem in expert shell programs. These are forward chaining and backward chaining method. The BT_expert rule base was designed to use forward chaining method. The solution of the forward chaining method starts from condition (IF) sentence and ends conclusion (THEN) sentence. If the conditions are satisfied, conclusion is true in “THEN” part.

![Fig. 3 The tree schema of KAPPA ES developed for boring tool selection](image1)

![Fig. 4 A sample rule used in BT_expert system](image2)

![Fig. 5 The connection of a rule (Barasecimi 1) with other rules](image3)

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Rule name</th>
<th>Task</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Barasecimi</td>
<td>To choose for boring tool</td>
<td>22</td>
</tr>
<tr>
<td>2</td>
<td>Baralamaoranı</td>
<td>To determine boring cartridge</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Radyissecimi</td>
<td>To determine insert</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Ucparametreleri</td>
<td>To determine cutting parameters</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>Uyari</td>
<td>To redirect user according to enter data and values</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Total:</strong> 72</td>
<td></td>
</tr>
</tbody>
</table>
Several pages were designed to input and output data for BT_expert. Visual objects were used on these pages that interact with the user. These pages are named as SESSION. When the BT_expert runs, the first page named “Boring Tool” is shown on the computer’s screen. Boring tool page is used to determine boring tools (fig. 6). First holed diameter, final holed diameter (D) and length (L) of hole have to be defined on this page. The system determines suitable boring cartridge from boring bar set according these data.

In addition, the BT_expert decides insert radius by considering half of difference between the first diameter and the final diameter. An insert radius is determined according to an experimental rule. It is known that insert radius is not smaller than chip thickness in machining operations. Then, the “Material selection” page (fig. 7) is switched after entering first diameter, final diameter (D) and length (L) on the first page. Material type is selected from this page. Finally, The system automatically select a boring cartridge, an insert and cutting parameters after entering hole information and material (fig. 7). In BT_expert, L/D rate is used in determining of cutting parameters. L/D rate are also important for set of boring tools (boring cartridge).

For example, when the final diameter of hole is 25 mm and the length of hole is 64 mm (fig.6), the program determines boring cartridge of which number is B3.22 by using the information in figure 3. In this example L/D rate is 4 (fig.8). BT_expert offers lower cutting speed (m/min) and feed rate (mm/rev) when L/D is higher than 2.5. The cutting speed (m/min) and the feed rate (mm/rev) by considering material type, L/D rate and insert radius. The system gives different cutting speed and feed rate when the finish cut calculated for bore decreases and the material or L/D rate change. The BT_expert system performs quickly, easily and safely selection of required boring tools, insert, cutting tools and cutting parameters. According to material of which is bored, the system can determine optimum boring cartridge, cutting speed, feed rate, insert quality and insert radius. Material selection entered on the page, first and last bore diameters and bore length are shown in the conclusion page of the BT expert system (fig 8)
The solution of the BT_expert for user inputs is shown on the solution page (fig. 8). BT_expert’s solution page has many parts. And, this pages that interact user has many active buttons. In other word, user can use page’s output data (get solution from BT_expert) for boring machining or user can run BT_expert program for new solution with page’s buttons. The solution output data is automatically painted with red colour. Red colour data is the best results. The best results that are boring cartridge, cutting speed, feed rate, and insert type and radius are shown blow of the page. User accept these parameters and use for hole machining. Otherwise, user runs the program by pressing “Run” button. In this case, all operation of BT_expert restarts.

IV. CONCLUSIONS

For precision bore machining, BT_expert system that determines the boring tool, the insert and cutting parameters, were implemented. This study will assist technicians and engineers to determine boring tool that widely used in precision bore machining, insert and cutting parameters. The system that has a simple structure can be used easily. Some additional studies can be done to improve this system. More technical data and details can be added to the database. The improved expert system can be evaluated in the machining sector. New boring tool, insert, material datum and cooling type (dry, coolant) can be added to the database. The user interface can be improved by adding new page and buttons. The tool holder manufacturing firms can develop software similar with BT_expert system besides the catalogues.

REFERENCES
Multi-Core Computing Application for Lyapunov Exponents Analysis of Chaotic Systems

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Abstract— The Lyapunov exponents analysis is one of the stability analyses of nonlinear systems. In addition, this analysis method is also used for obtaining information about chaos that is a behavior of nonlinear systems. In this study, it is explained by an example application that the chaotic behavior analysis of a nonlinear chaotic system based on the Lyapunov exponents can be performed faster by a Multi-Core CPU. For this application, MATLAB parallel processing toolbox has been used and the parallel computing performance of the application has been analysed by using obtained results.

Keywords— Chaotic systems, Parallel processing, Lyapunov exponents

I. INTRODUCTION

The models of nonlinear systems are used for modelling and assessing the behavior of the systems that we encounter. One of the behavior types of the nonlinear systems is the chaotic behavior. For a nonlinear system to show chaotic behavior, the system’s parameters and initial values must be appropriate to the chaotic behavior. The nonlinear systems which show chaotic behavior for the appropriate values are called chaotic systems. With the Lyapunov exponents analysis it can be determined that whether the system exhibits chaotic behavior or not for the given parameters values.

The Lyapunov exponent analysis is used widely to explain dynamical behavior of nonlinear systems [1-4]. The largest Lyapunov exponent to be positive means the system is chaotic. The algorithms that calculate the Lyapunov exponents from time series are available [5-9]. In addition to this, the programs or codes that use these algorithms are also available [10-14]. All these algorithms, programs, or codes calculate the Lyapunov exponents for a certain parameters values or as a function of a single system parameter.

For examining the behavior of the chaotic systems, analyses which employ the Lyapunov exponent spectra are commonly used. The calculation of the Lyapunov exponents for a single system parameter value does not take too much time. However to obtain the Lyapunov exponents spectrum, the Lyapunov exponents must be calculated for too many parameter values. For a precise analysis, the number of the system parameter values must be as high as possible. This makes obtaining better spectrum take much more time.

In this study which differs from studies in the literature, the Lyapunov exponent spectrum obtained faster via parallel computing application in a PC with multi-core CPU. For this application MATLAB Parallel Computing Toolbox was used. The performance of the application was assessed according to speed and efficiency.

In the next section of this article, the algorithm that uses Lyapunov exponent is introduced. In the third part, Lorenz chaotic system and its Lyapunov exponent spectrum is presented as an example. In the fourth part, the realized parallel computing application is mentioned. In the fifth part the performance of the parallel computing is assessed. In the last part, discussion and evaluation is given.

II. LYAPUNOV EXPONENTS ANALYSIS

The Lyapunov exponents are calculated analytically as in Equation 1 [6].

\[ \lambda_i = \lim_{t \to \infty} \left( \ln \frac{P_i(t)}{P_i(0)} \right) \]

(1)

Fig. 1. Divergence of two trajectories

Here \( \lambda_i \) and \( p_i \) represents the Lyapunov exponents and the vectors given in Fig. 1 respectively. As it can be seen in the equation 1, the values of Lyapunov exponents depend on the distance between chosen points that are at two infinitesimally close trajectories in the phase portraits of the chaotic system. Moreover, the number of the Lyapunov exponents also equals to the dimension of the chaotic system.

To calculate the Lyapunov exponents analytically the values of \( p_i \) must be determined. Determining the values requires many different processes [5, 6]. As an alternative to...
this, many algorithms for calculating the Lyapunov exponents from time series have been proposed. [5-9]. In this study, the MATLAB code that is proposed by [11] which employs the algorithm in [6] is used.

The signs of the Lyapunov exponents give information about the dynamical behaviors of the systems. For a 3-D system, the dynamical behaviors of the system according to the signs of the Lyapunov exponents are given in Table 1. If one of the Lyapunov exponent is positive, systems exhibits chaotic behavior. In this way, the chaotic systems can be determined with the Lyapunov exponent analysis.

Another usage area of the Lyapunov exponents analysis is calculating the chaotic dimension [5, 6]. The chaotic dimension gives information about how chaotic the system behavior is. The chaotic dimension is calculated as in Equation 2 [6].

\[
d_f = f + \sum_{i=1}^{j} \lambda_i / j^{j+1}
\]

Here the term \( j \) is determined according to \( \sum_{i=1}^{j} \lambda_i > 0 \) and \( \sum_{i=1}^{j} \lambda_i < 0 \).

III. PARALLEL COMPUTING APPLICATION OF THE LYAPUNOV EXPONENT ANALYSIS

Nowadays most of the PCs have multi-core CPUs. To use this feature to its full potential in Computer-aided computation, parallel computing techniques are required. There are two basic approaches in the parallel computing techniques. The first one is task parallel technique in which the different processes are done simultaneously and the other one is data parallel technique in which the pieces of a huge data undergo to the same process in parallel.

To obtain The Lyapunov exponents spectrum, the Lyapunov exponents are calculated for many different values of a parameter of the nonlinear system. The graph of the Lyapunov exponents is drawn with respect to the system parameter. By examining this spectrum, the chaotic behavior of the system is commented on.

In this study, faster obtainment of the Lyapunov exponents spectrum with data parallel technique in a multi-core CPU PC was realized. The realized parallel computing application is seen in Fig. 2.

![Fig. 2. The realized multi-core computing application](image)

The parallel computing application in Fig. 2, to obtain the Lyapunov exponents spectrum n core processor is used. Moreover the system parameter take m number values between a and b. Each processor calculates Lyapunov exponents for m/n number of system parameter values.

After this, these results are brought together to obtain the Lyapunov exponent spectrum. The parallel computing application mentioned above was realized with parfor loop in MATLAB Parallel Computing Toolbox.

A. MATLAB Parallel computing toolbox and Parfor Loop

MATLAB Parallel Computing Toolbox is developed for parallel computing problems by using multi-core processors, graphic processing units (GPUs) and computer clusters. By using parfor which executes loop iterations in parallel, special series types and parallelized numerical algorithms it is possible to developed parallel computing applications without programming CUDA or MPI [15].

Parfor (parallel-for) in MATLAB iterates statements in the loop over a specified range of values like standard for-loop but in parallel. The logic of operation of parfor is shown in Fig. 3 MATLAB Client runs the parfor loop code while the iterations are run on MATLAB Workers [15]. Each Workers are run on different core. MATLAB parfor structure is shown in Fig. 3. In this structure the parallelization can be done up to with twelve workers.
B. Obtaining Lyapunov Exponents Spectrum with Parallel Computing: Lorenz Chaotic System

In this section, the Lyapunov exponents spectrum of a common chaotic system, Lorenz system, was obtained via parallel computing. The Lorenz system is defined as in Equation 3.

\[
\begin{align*}
\dot{x} &= \alpha(y-x) \\
\dot{y} &= x(\beta - z) - y \\
\dot{z} &= xy - \lambda z
\end{align*}
\] (3)

The parameters of the Lorenz system in Equation 3 must be at certain values in order to the system exhibits chaotic behavior. To determine the parameters values the Lyapunov exponents spectrum is obtained. In Fig. 4, Lorenz system’s Lyapunov exponents spectrum in terms of \( \alpha \) is given. This spectrum was obtained for the parameter \( \alpha \)'s values are between 5 and 20, the parameters \( \beta \) is 28, \( \lambda \) is 8/3 and the initial values is 1,1,1 for \( x, y, \) and \( z \) respectively.

As it can be seen in Fig. 4, there is no positive Lyapunov exponent if the parameter \( \alpha \)'s value is between 5 and 5.6 or 18.4 and 20, and for these ranges two of the Lyapunov exponents are zero and the other one is negative \((0,0,-)\), thus the system shows two-tours behavior. When the parameter \( \alpha \)'s value is between 5.8 and 18.3 there is a positive Lyapunov exponent, hence the system shows chaotic behavior.

The time results in Table 3 was acquired by using sequential and parallel computing with 2, 4, 6 and 8 cores for the obtainment of the spectrum in Fig. 4. The specifications of the multi-core PC is given in Table 2. The performance assessment of the parallel computing application was done in section 3.3 by evaluating the results in Table 3.

<table>
<thead>
<tr>
<th>CPU</th>
<th>i7-4700HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Cores</td>
<td>8</td>
</tr>
<tr>
<td>CPU frequency</td>
<td>2.40 GHz</td>
</tr>
<tr>
<td>RAM</td>
<td>16 GB</td>
</tr>
<tr>
<td>Operating System</td>
<td>Win 8.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3. Lyapunov Exponents Spectrum Obtainment Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>1112.600s</td>
</tr>
</tbody>
</table>

C. The Performance Assessment of the Parallel Computing

In the parallel computing applications, the properties of the computer, the algorithm, and computing load and complexity have an impact on the performance of the application. For this reason, in a parallel computing with an n-process unit, the computing speed cannot reach n times of that of non-parallel computing. Hence, efficiency and cost are taken consideration, in parallel computing. Equations 4, 5 and 6 are used in assessment of the parallel computing to calculate speed, efficiency and cost respectively [16].

\[
S_p = \frac{T^*}{T_p} \quad (4)
\]

\[
E_p = \frac{S_p}{p} \quad (5)
\]

\[
C_p = T_p \times p \quad (6)
\]

In these equations, \( p \) is the number of processor unit, \( T^* \) is the elapsed time when single-core processor is used, \( T_p \) is the elapsed time when \( p \)-core processor is used and \( S_p, E_p, \) and \( C_p \) are defined as speedup, efficiency and cost respectively.

In Fig. 5, the graphs of the performance analysis of Table 3 is given. These graphs includes speedup, efficiency and cost analysis for 2, 4, 6 and 8 core process units.
When Fig. 5 is examined, the result is obtained faster with parallel computing. As the number of the core increases the speed of the calculation is increased. However, as the number of the core increases the cost and efficiency for the obtainment of the Lyapunov exponents spectrum with parallel computing does not improve like speedup. In fact, the efficiency decreases dramatically and the cost increases as the number of the core increases. This situation is encountered in most of the application in PCs. The reason for this the increase in the parallel overhead with the number of the core used and reaching the maximum capacity of PC’s data transmission rate. This leads to negative effect on both cost and efficiency. Another reason for low efficiency and high cost is the CPU has not real 8 cores but virtual 8 cores. Thus, the increase in speedup and efficiency is much more in the computing application with 2 and 4 cores.

In this study, faster obtainment of the Lyapunov exponents spectrum is realized. For more efficient result, more appropriate hardware and programs should be employed. Moreover, if the dimension of the computing program increases the efficiency and cost will be at an acceptable level.

**IV. CONCLUSIONS**

In the proposed study, an application of parallel computing for faster obtainment of Lyapunov exponents spectrum is realized with a multi-core PC. In the application, as the number of core used increases the speed of the computing application increases, but the cost increases and efficiency decreases dramatically because of the PC’s limitations such as parallel overhead and data transmission rate .However, employing parallel computing for obtainment of the Lyapunov exponents spectrum is a sound approach when considering the speed of the computing. For more complex systems, the number of values to be calculated and the dimension of the problem increases, hence the efficiency of the parallel computing increases. In a future study, the Lyapunov exponents analysis of more complex systems will be examined.
Estimation of Turkey Electric Energy Demand Until Year 2035 Using TLBO Algorithm

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*Selcuk University, Konya/Turkey, harun_uguz@selcuk.edu.tr

Abstract— In this study, the estimation of Turkey primary electric energy demand until 2035 is tried to estimate by using Teaching-Learning Based Optimization (TLBO) Algorithm. Two models are proposed which are based on economic indicators TLBO algorithm linear energy demand (TLBOEDL) and TLBO algorithm quadratic energy demand (TLBOEDQ). In both of these two models the indicators used are Gross Domestic Product (GDP), population, importation and exportation. After a comparison of these two models with real values between 1979 and 2005 years, it is applied to the estimation of Turkey electric energy demand until 2035 by three different scenario. The estimation results are suitable with the estimation of Turkey total primary energy supply of 2013 Energy Report of World Energy Council Turkish National Committee (WEC-TNC).

Keywords— Teaching Learning Based Optimization (TLBO) Algorithm, Energy Demand Estimation, TLBOEDL Model, TLBOEDQ Model, Turkey Energy Report 2013

I. INTRODUCTION

Energy is the most important need of developed and developing countries. Energy is an indispensable fact which its importance has been growing gradually. It is the most important means in the development of countries. Energy consumption has been increased with the growth in world population. The economic growth leads to energy consumption and energy consumption leads to economic growth [1]. Therefore the energy demand has been increasing despite important nuclear power plant accidents and financial crisis. Foreign energy dependency of Turkey as % 70 percentage obliges the special policies and special behavior styles as society on energy subject [2].

To meet the electrical energy of society economically, supply, demand, transmission, contribution and pricing policies should be constituted effectively. Moreover, ease of use of electrical energy for consumers, non-storability of electrical energy increases the importance of demand studies on electrical energy area [3]. Energy demand estimation has a critical role in energy agreement between countries. The excessive deviation leads to the economical deficits.

Although demand studies on energy have been studies in Western countries for a long time, the studies have accelerated at the end of 1990s in our country. State Planning Organization, State Statistical Institute and Ministry of Energy and Natural Sources have been used the mathematical models for the energy demand at the last of 1970s [4].

Recently, many studies on the Turkey primary energy demand have been done. In these studies, different methods, different scenarios with various data and variables for many terms have been used [3]. Some studies on this research area are the energy demand estimation by Artificial Neural Networks (ANN) [8-10], energy demand by Ant Colony Optimization (ACO) [11] and energy demand estimation by hybrid Algorithm [12].

Generally, any event which is wanted to model in terms of estimation by mathematically, as the numbers of variables are getting increased, correct estimation possibility decreases [3]. In this study, the estimation of Turkey energy demand until 2035 is try to estimate by using some economical variable indicators such as Gross Domestic Product (GDP), population, importation and exportation.

II. TEACHING LEARNING BASED OPTIMIZATION (TLBO) ALGORITHM

TLBO algorithm is a social based optimization algorithm which depends on interaction between students and teachers in a class. At every step of algorithm, successful students are elected and the best students have been determined [13].

It has three parameters which is the number of students, number of classes and iteration number. TLBO algorithm has two phases which are teacher and student phases.

At teacher phase of the algorithm, students learn from the teacher by imitating. Teacher is the most experienced and the most informed person so the best student can learn as much as the teacher.
Between teacher and student’s learning capacity, there is an average difference called difference mean and it is defined as Eq. 1.

\[
\text{Difference Mean}_{i} = r_{i}(X_{j,best,i} - T_{M,i})
\]

(1)

where \( r_{i} \) is a random number between 0 and 1, \( X_{j,best,i} \) is the result of teacher (the best result) and \( T_{f} \) is teaching factor between 1 and 2.

\( T_{f} \) is defined as Eq. 2,

\[
T_{f} = \text{round}[1 + \text{rand}(0,1) \{1.2\}]
\]

(2)

If difference mean is better than present result, Eq. 2 is arranged as Eq. 4, the best function result is given by Eq. 3.

\[
X'_{j,best,i} = X_{j,best,i} + \text{Difference Mean}_{j,k,i}
\]

(3)

where \( X'_{j,best,i} \) is the best function result accepted.

After teacher’s phase, all best function values are kept to use at student’s phase. At this stage, students learn the knowledge by interacting and by discussing between them. If a student is more knowledgeable, the other is updating himself by interaction.

\[
P_{i} = \text{random between 1 and 2}.
\]

(4)

where \( X_{total-P,i} \) and \( X_{total-Q,i} \) are updated values of \( X_{total-P,i} \) and \( X_{total-Q,i} \).

If \( X_{total-P,i} > X_{total-Q,i} \) \( X'_{j,P,i} \) is obtained as Eq. 5

\[
X'_{j,P,i} = X_{j,P,i} + r(X_{j,P,i} - X_{j,Q,i})
\]

(5)

and if \( X_{total-Q,i} > X_{total-P,i} \) \( X'_{j,P,i} \) is obtained as Eq. 6

\[
X'_{j,P,i} = X_{j,P,i} + r(X_{j,Q,i} - X_{j,P,i})
\]

(6)

\( X'_{j,P,i} \) is accepted as the best function value [13].

III. ESTIMATION OF TURKEY ENERGY DEMAND WITH TLBO (TLBOED)

Economical variable indicators such as Gross Domestic Product (GDP), population, importation and exportation for energy demand estimation is try to estimate by using TLBO algorithm. TLBOEDL and TLBOEDQ models are proposed depending on economic indicators. It is seen from the literature that Linear and quadratic models have been studied commonly [11, 12, 14-16].

Economic indicators of Turkey between 1979 and 2005 are given in Table I [17, 18].

<table>
<thead>
<tr>
<th>Year</th>
<th>Energy Demand (MTOE)</th>
<th>GDP ($10^9)</th>
<th>Population (10^6)</th>
<th>Import ($10^9)</th>
<th>Export ($10^9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>30.71</td>
<td>82.00</td>
<td>43.53</td>
<td>5.07</td>
<td>2.26</td>
</tr>
<tr>
<td>1980</td>
<td>31.97</td>
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<td>1981</td>
<td>32.05</td>
<td>72.00</td>
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<td>8.93</td>
<td>4.70</td>
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<td>46.69</td>
<td>8.84</td>
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<td>1983</td>
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<td>50.31</td>
<td>11.34</td>
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<td>1986</td>
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<td>75.00</td>
<td>51.43</td>
<td>11.10</td>
<td>7.46</td>
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<tr>
<td>1987</td>
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<td>14.34</td>
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<td>58.25</td>
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<td>60.42</td>
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<td>1998</td>
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<td>65.00</td>
<td>45.92</td>
<td>26.97</td>
</tr>
<tr>
<td>1999</td>
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<td>187.00</td>
<td>66.43</td>
<td>40.67</td>
<td>26.59</td>
</tr>
<tr>
<td>2000</td>
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<td>200.00</td>
<td>67.42</td>
<td>54.50</td>
<td>27.78</td>
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<td>146.00</td>
<td>68.37</td>
<td>41.40</td>
<td>31.33</td>
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<td>2002</td>
<td>78.33</td>
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<td>69.30</td>
<td>51.55</td>
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<td>2003</td>
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<td>239.00</td>
<td>70.23</td>
<td>69.34</td>
<td>47.25</td>
</tr>
<tr>
<td>2004</td>
<td>87.82</td>
<td>299.00</td>
<td>71.15</td>
<td>97.54</td>
<td>63.17</td>
</tr>
</tbody>
</table>

The linear model proposed by TLBO algorithm as in Eq. 7,

\[
E_{TLBOEDL} = w_1 X_1 + w_2 X_2 + w_3 X_3 + w_4 X_4 + w_5
\]

(7)

Quadratic model equation is given in Eq. 8,

\[
E_{TLBOEDQ} = w_1 X_1 + w_2 X_2 + w_3 X_3 + w_4 X_4 + w_5

+ w_6 X_1 X_2 + w_7 X_1 X_3 + w_8 X_1 X_4

+ w_9 X_2 X_3 + w_{10} X_2 X_4 + w_{11} X_3^2 + w_{12} X_4^2

+ w_{13} X_3 X_4 + w_{14} X_2^2 + w_{15}
\]

(8)

\( w_i \) and \( X_i \) coefficients are used in two proposed models. \( w_i \) coefficients are defined as design parameters. There isn’t any limitation for design parameters \((-\infty < w_i < +\infty)\).

\( X_1, X_2, X_3, X_4 \) are constants and these are defined as Gross Domestic Product (GDP), population, import and export
respectively. The objective function in energy demand estimating is given by Eq. 9,
\[ \min f(v) = \sum_{r=1}^{m} (E_f^{observed} - E_f^{predicted})^2 \]  
(9)

where \( E^{observed} \) and \( E^{predicted} \) are the actual and predicted energy demand, respectively, \( m \) is the number of observations.

We give the algorithm of our TLBOED method below:

Step 1. Define the optimization problem and initialize the optimization parameters.
- Initialize the population size \( (P_n) \), number of generations \( (G_n) \), number of design variables \( (D_n) \), and limits of design variables \( (U_1, L_1) \).
- Define the optimization problem as Eq. 10:
\[ \min f(v) = \sum_{r=1}^{m} (E_f^{observed} - E_f^{predicted})^2 \]  
(10)

Subject to \( w_i \in w_i = 1,2,\ldots,D_n \)
where \( f(v) \) is the objective function, \( w \) is a vector for design variables such that \( -\infty < w_i < +\infty \).

Step 2. Initialize the population.
- Generate a random population according to the population size and number of design as Eq. 11 variables.
\[ \text{population}= \begin{bmatrix} w_{1,1} & w_{1,2} & \ldots & w_{1,D} \\ w_{2,1} & w_{2,2} & \ldots & w_{2,D} \\ \vdots & \vdots & & \vdots \\ w_{P_n,1} & w_{P_n,2} & \ldots & w_{P_n,D} \end{bmatrix} \]  
(11)

Step 3. Teacher phase.
- Calculate the mean of the population column-wise, which will give the mean for the particular subject as Eq. 12,
\[ M_{i,D}=[m_1, m_2, \ldots, m_D] \]  
(12)

The best solution will act as a teacher for that iteration in Eq. 13,
\[ W_{teacher} = W_f(W) = \min \]  
(13)

The teacher will try to shift the mean from \( M_{i,D} \) towards \( W_{teacher} \) which will act as a new mean for the iteration. So,
\[ M_{new,D} = W_{teacher,D} \]  
(14)

The difference between two means is expressed as Eq. 15,
\[ \text{Difference},_D = r (M_{new,D} - T_F M_{i,D}) \]  
(15)

The value of \( T_F \) is selected as 1 or 2. The obtained difference is added to the current solution to update its values using Eq. 16.
\[ W_{new,D} = W_{old,D} + \text{Difference},_D \]  
(16)

Accept \( W_{new} \) if it gives better function value.

Step 4. Learner phase.
- Learner modification is expressed as
For \( i = 1 : P_n \)
Randomly select two learners \( W_i \) and \( W_j \), where \( i \neq j \)
If \( f(W_i) < f(W_j) \)
\[ W_{new,i} = W_{old,i} + r (W_i - W_j) \]
Else
\[ W_{new,i} = W_{old,i} + r (W_j - W_i) \]
End If
End For
Accept \( W_{new} \) if it gives a better function value.

Step 5. Termination criterion.
- Stop if the maximum generation number is achieved; otherwise repeat from Step 3.

IV. EXPERIMENTAL STUDIES

TLBOED algorithm is proposed for Turkey energy demand estimation between 1979 and 2005 years by using economic indicators taken from MENR. Minimum objective function is obtained by calculating for TLBOEDL model. In Eq. 17, population size \( (P_n) \) is taken as 25, number of design variables \( (D_n) \) are taken as 5 and the number of generations \( (G_n) \) is taken as 1000 and \( f(v)_{TLBOEDL} \) is obtained as 41,712.
\[ E_{TLBOEDL} = 0,003805955X_1 + 1,9122747919X_2 + 0,3735435225X_3 - 0,4835157988X_4 - 55,89091016 \]  
(17)
Minimum objective function is obtained by calculating for TLBOEDQ model. In Eq. 18, population size (P) is taken as 25, number of design variables (Dn) are taken as 15 and the number of generations (Gn) is taken as 10,000. Minimum f(v)TLBOEDQ is obtained as 19,32921.

\[
E_{TLBOEDQ} = -0.01833664807X_1 + 0.1271526268X_2
-0.7303814145X_3 + 1.5173167741X_4
+0.0057624768X_5 + 0.0118978356X_6X_7
-0.0079494952X_8X_9 - 0.0013078678X_2X_3
-0.0149756126X_4X_5 + 0.0365796927X_4X_6 (18)
-0.0017245010X_7X_8 + 0.0096564193X_2^2
-0.0234475391X_3^2 - 0.0197717121X_4^2
-2.0471885591
\]

TLBOEDL and TLBOEDQ estimation models were executed for 50 times and best results were considered by given parameters in Eq. 17 and Eq. 18.

TLBOEDL and TLBOEDQ models which are formed by taking the data from Table II are effective and successful according to data between 1996 and 2005 years.

In Table II, the biggest decrease in energy demand is in 2001. In Table I, a considerable decrease is seen for the same year 2001. This situation results from the economic crisis in 2001.

| Years | Observed energy demand (MTOE) | Estimated energy demand (MTOE) | Relative errors (%)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Linear</td>
<td>Quadratic</td>
<td>Linear</td>
</tr>
<tr>
<td>1996</td>
<td>69.86</td>
<td>69.71</td>
<td>69.85</td>
</tr>
<tr>
<td>1997</td>
<td>73.78</td>
<td>72.32</td>
<td>72.71</td>
</tr>
<tr>
<td>1998</td>
<td>74.71</td>
<td>73.30</td>
<td>74.28</td>
</tr>
<tr>
<td>1999</td>
<td>76.77</td>
<td>74.18</td>
<td>75.27</td>
</tr>
<tr>
<td>2000</td>
<td>80.50</td>
<td>80.71</td>
<td>80.96</td>
</tr>
<tr>
<td>2001</td>
<td>75.40</td>
<td>75.71</td>
<td>74.79</td>
</tr>
<tr>
<td>2002</td>
<td>78.33</td>
<td>79.13</td>
<td>79.68</td>
</tr>
<tr>
<td>2003</td>
<td>83.84</td>
<td>82.36</td>
<td>83.70</td>
</tr>
<tr>
<td>2004</td>
<td>87.82</td>
<td>87.19</td>
<td>87.30</td>
</tr>
<tr>
<td>2005</td>
<td>91.58</td>
<td>93.10</td>
<td>91.92</td>
</tr>
</tbody>
</table>

Three different scenario have been constituted for Turkey 2013-2035 energy demand estimation. Scenarios are made by utilizing the data from Turkish Standards Institute [17]. Scenarios are compared to 2006-2012 demand [18] and our estimation models in Table III, Table IV, and Table V. At later stage, estimations until 2035 is obtained.

| Years | Observed energy demand (MTOE) | Estimated energy demand (MTOE) | Relative errors (%)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>99.59</td>
<td>95.96</td>
<td>-3.78</td>
</tr>
<tr>
<td>2007</td>
<td>107.63</td>
<td>98.90</td>
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<tr>
<td>2008</td>
<td>106.34</td>
<td>101.94</td>
<td>-4.32</td>
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<tr>
<td>2009</td>
<td>106.14</td>
<td>105.09</td>
<td>-1.01</td>
</tr>
<tr>
<td>2010</td>
<td>109</td>
<td>109.34</td>
<td>-0.61</td>
</tr>
<tr>
<td>2011</td>
<td>115</td>
<td>111.71</td>
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</tr>
<tr>
<td>2012</td>
<td>121</td>
<td>115.19</td>
<td>-5.04</td>
</tr>
</tbody>
</table>

Table III: Energy demand estimation of TLBOED between 2006 and 2012 years according to scenario 1.

| Years | Observed energy demand (MTOE) | Estimated energy demand (MTOE) | Relative errors (%)
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>99.59</td>
<td>94.53</td>
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<tr>
<td>2007</td>
<td>107.63</td>
<td>97.86</td>
<td>-9.98</td>
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<td>100.35</td>
<td>-5.97</td>
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<td>102.91</td>
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<td>-6.22</td>
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<tr>
<td>2012</td>
<td>121</td>
<td>111.07</td>
<td>-8.94</td>
</tr>
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</table>

Table V: Energy demand estimation of TLBOED between 2006 and 2012 years according to scenario 3.

From the Tables (III-V), the estimations by TLBOED model is close to the observed demand values. According to these tables,
decrease in the demand in 2008-2009 years shows that the crisis worldwide was affected the Turkey as little.

Scenarios are compared to Turkey primary energy supply and demand estimations according to World Energy Council Turkey National Committee.

Scenario 1: It is assumed that the average growth rate of GDP is 4.7%, population growth rate is 0.11%, import growth rate is 4.5%, and export growth rate is 2% during the period of 2013-2035. The obtained results are compared to WEC-TNC Turkey 2013 Energy Report in Table VI and Figure 1.

Scenario 2: It is assumed that the average growth rate of GDP is 5%, population growth rate is 0.12%, import growth rate is 5%, and proportion of import covered by export is 2.5% during the period of 2013-2035. The obtained results are compared to Turkey 2013 Energy Report in Table VI and Figure 2.

Scenario 3: It is assumed that the average growth rate of GDP is 4%, population growth rate is 0.09 %, import growth rate is 4%, and export growth rate 2% during the period of 2013-2035. The obtained results are compared to WEC-TNC Turkey 2013 Energy Report in Table VI and Figure 3.

In Table VII, energy demand estimations which was done in some years according to WEC-TNC Turkey Energy Report 2013 are seen [2]. The graphics in Figures (1-3) is obtained as a result of a comparison in Table VII.

Table VII: Energy supply and demand estimations realized according to WEC-TNC Turkey Report 2013 [2].

<table>
<thead>
<tr>
<th>Years</th>
<th>Estimated energy demand (MTOE) (WEC-TNC) [2]</th>
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</thead>
<tbody>
<tr>
<td>2015</td>
<td>129</td>
</tr>
<tr>
<td>2020</td>
<td>146</td>
</tr>
<tr>
<td>2025</td>
<td>157</td>
</tr>
<tr>
<td>2030</td>
<td>165</td>
</tr>
<tr>
<td>2035</td>
<td>208</td>
</tr>
</tbody>
</table>

Table VI: Energy demand estimation between 2013 and 2035 years according to scenarios (1-3) in MTOE.

<table>
<thead>
<tr>
<th>Years</th>
<th>Scenario 1 (MTOE)</th>
<th>Scenario 2 (MTOE)</th>
<th>Scenario 3 (MTOE)</th>
</tr>
</thead>
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<tr>
<td></td>
<td>TLBOEDL</td>
<td>TLBOEDQ</td>
<td>TLBOEDL</td>
</tr>
<tr>
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<td>120.8</td>
</tr>
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<td>126.4</td>
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<td>129.1</td>
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<tr>
<td>2021</td>
<td>152.6</td>
<td>164.5</td>
<td>158.5</td>
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<tr>
<td>2022</td>
<td>157.6</td>
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<td>164.1</td>
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<td>2023</td>
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<td>191.5</td>
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<tr>
<td>2029</td>
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<td>211.4</td>
<td>210.7</td>
</tr>
<tr>
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<td>216.8</td>
<td>218.6</td>
</tr>
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<td>2031</td>
<td>211.6</td>
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<tr>
<td>2032</td>
<td>218.9</td>
<td>226.4</td>
<td>235.4</td>
</tr>
<tr>
<td>2033</td>
<td>226.4</td>
<td>230.5</td>
<td>244.4</td>
</tr>
<tr>
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<td>234.2</td>
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<td>253.8</td>
</tr>
<tr>
<td>2035</td>
<td>242.3</td>
<td>236.5</td>
<td>263.6</td>
</tr>
</tbody>
</table>

Figure 1: Energy demand estimations realized between 2006 and 2035 years according to scenario 1 in MTOE.

Figure 2: Energy demand estimation realized between 2006 and 2035 years according to scenario 2 in MTOE.
Countries must balance the energy supply and demand. Therefore they make agreements between them. Our country is a foreign dependent country as energy sources. This dependency is obliged us to an appropriate and consistent energy policy with the other countries. Energy demands according to Country needs will contribute the savings to the national economy. Excessive deviations in estimating country demands will result the much more natural gas import so the dependency in energy will be risen.

In this study, TLBOEDL and TLBOEDQ models make a demand estimation in accordance with given scenarios and these models can be useful in estimation analysis. Especially scenario 3 with its two models is consistent with WEC-TNC Turkey Energy Report 2013.

V. CONCLUSION

Countries must balance the energy supply and demand.

REFERENCES

A Review of Automatic Author Identification Task

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Abstract — Nowadays, the author of the recognition process, the development of technology and is made to find solutions to some problems emerged with the spread of knowledge. Some of these problems, author unknown documents, e-mail the threat, and the author of the criminal investigation is to determine the author of the text can’t be sure who. Authors identification is the process of determining who is the author of a text written in any language. This document, based on the language made the last 15 years and regardless of the language, the author presents a review about the identification their work. The authors recognize the language-dependent work in the language of the syntax of specific words in the uses of the language by the author and the word of their arrangement with the order in which to do that by paying attention to the author of the text is the process of estimating different algorithms starting from here. The author of the independent study of the language of the unknown text with the character n-gram methods of machine learning is the process after the calculation of weight and estimating based on the text of the previous authors using artificial neural networks. Authors frequently used in the identification, used in the selected article, methods have been investigated and their authors compared the accuracy of the identification. Authors alone can’t fully identification the many methods used to give accurate results and language used by the author using some combination of these methods and it was emphasized that the words have to look at trends in the author's writings.

Keywords— Author identification, Writer Identification, Language-Dependent Studies

I. INTRODUCTION

Document classification and verification is a matter of in natural language studies. If our goal is to separate the types of documents. We use properties, properties that are used to find the author of a document, may be different from each other. Author identification work is a subject studied for many years, artificial neural networks, statistical methods and machine learning, such techniques are used for author identification. With the advancement of technology, who written by the unknown online text, author identification work has increased. The authors identify a lead in the other study authors are handwritten identification process [5]. In recent years, terrorist acts in the use of online messages, these events may be subject to messages, to distinguish, and made studies on the presence of the author, language-dependent studies, language syntax structure that makes identifying the author examines how writers use. We follow a columnist, without name and even when the article was published on a different page, we can guess who wrote it in writing. We have become used to the author's writing style because we follow. We could do this to separate, we can make the computer automatically? The answer to this question is yes, of course. Every writer has a unique style. This style is converted to a mathematical function author recognition process is realized. Turkish studies done on this subject is limited [1]. Author identification is classified into three different research areas which include authorship identification, authorship verification, and authorship characterization [2]. Authorship attribution determines the most probable author of an anonymous document by comparing it with the known available documents. Authorship characterization is helpful to determine the characteristics like gender, age etc. [3]. Author identification of physical and electronic documents, it is close to an area of research, and many researchers are currently working in this research field [4].

This paper consists of three parts. the first part will be released in the definition of author identification. In the second part, the author identification the field, made different studies. In the third part of the study measurements it is included.

II. AUTHOR IDENTIFICATION AND AUTHOR ANALYSIS

Author identification the unknown author of the document the author is no process. This process, artwork, criminal investigation, online messages and handwritten etc. It is working in the fields. However, the online documentation for writing verification can be used to solve various crime cases such as extortion and terrorist activities [9]. Online messages, there are difficulties to implement the writer identification. These challenges are; Length of Online document is short, an online message, there is less regular font style, knows the right words to be
written, Online documentation style and structure is different from the normal text format documents. The different languages spoken in the world, making it difficult to the fight against international cybercrime. along with the challenges mentioned, crime analysis of online posts by author analysis it can be used for various applications. [2]. authorship analysis has been applied to various cybercrimes. for example, malware [6,7], it is used in the web spam measures [8].

The author analysis two different machine learning algorithm is used as the basis. they are supervised and unsupervised machine learning. The supervised learning algorithms are also suitable when the information of both training and testing data that is the data’s label is known beforehand [3].

III. AUTHOR CLASSIFICATION

Today, a lot of sources of information is held in the form of unstructured text documents in electronic form. In this case, users can find what they are looking for them, an increasing number of documents from the documents research, analysis, revealed the deal requires the grouping. automatically parses documents to predetermined class system being developed to find solutions to this situation. Recently, Support Vector Machine, Naive Bayes, K-Nearest a machine learning method is used in the neighbour-hood, such as text classification work. Artificial Immune Systems is a method has not been tested before, and when appropriate work in text classification feature vectors used in the trials, particularly in species recognition system has shown that successful results. They are frequently used classification methods;

Naive Bayes (NB). Classic Naïve Bayes algorithm often used in the determination of a document with the word class and the class of the joint probability [35].

Support Vector Machines (SVM). Class biggest margin separating from each other, aims to set a distinctive linear function. Linear inseparable as examples for examples, moved to another higher-dimensional space could be divided and linear classification that is done in space.

Random Forests (RO). Breiman to produce a single decision tree Instead, each trained a large number of different training sets, He proposed the merging of the multivariate decision tree. Different sets of training boot (bootstrap) and random by selecting the feature created from the original training set. Very variable decision trees obtained by CART algorithm [36]. Before any decision tree gives its decision, forest in-class maximum votes, which considered the final decision it is and incoming test data is included in that class.

K-Nearest Neighboring (K-NN). class of data which will feature vector value is based on the principle of finding the closest feature vector k. Found nearest feature vectors, Euclidean distance is used. The vector k found that most of what class, the class label is defined as a class of data to be sorted.

IV. STUDIES ON AUTHOR IDENTIFICATION

Document classification and author identification studies so far, various features are used. Burrows [10] based on the word wealth characteristics, Stamatelatos and friends [11] various combinations of syntactic features of style, Fürnkranz [12] n-grams, Authorship analysis is the study of linguistic and computational characteristics of the written documents of individuals [14,15]. special article features extracted from text written in advance of individuals can be used to distinguish another person [16]. writing styles can be categorized in five different types, these namely lexical, syntactic, structural, content-specific, and idiosyncratic features [4,13]. Authorship analysis has been very successful for resolving authorship identification disputes over literary and conventional writings [17]. online document analysis is more difficult. [18]. There are many applications for plagiarism detection and similarity determination. advancing technology, facilitate their replication and spread [19]. Similarly, taking different user names of customers, protect the reputation of the company [20]. have developed techniques for detecting aliases in online systems (e.g., eBay) by analyzing the users’ feedback. Abbasi et al [21]. The first approach conducts verification using classifica-tion; three different classifiers are investigated, namely, Adaboost.M1, Bayesian Network, and Discriminative Multinomial Naive Bayes (DMNB). The second approach conducts verification by regression; three different classifiers were studied including linear regression, SVM with Sequential Minimum Optimization (SMO), and SVM with RBF kernel. The feature set was composed of 292 attributes, which included lexical (collected either in terms of characters or words), syntactic (punctuation and function words), idiosyncratic (spelling and grammatical mistakes) and content-specific (keywords commonly found in a specific domain). Experimental evaluation of the proposed approach, using the Enron e-mail corpus and by analyzing 200 e-mails per author, yielded EER ranging from 17.1% to 22.4% [22]. Canales et al. trained a K-Nearest Neighbor (KNN) classifier with 82 stylistic features including 49 character-based, 13word-based, and 20 syntactic features [23]. In addition, they combined stylometry and keystroke dynamics analysis for the purpose of authenticating online test takers. They experimented with 40 students with sample document size rang-ing between 1710 and 70300 characters, and obtained as performances (FRR=20.25%, FAR=4.18%) and (FRR=93.46%, FRR=4.84%) when using separately keystroke and stylometry, respectively. The combination of both
types of features yielded EER=30%. They concluded that the feature set must be extended and certain type of punctuations may not neces-sarily represent the style of students when taking online exams [23]. For the author analyzes explored the use of stylogy for online posts [24]. The technique was based on a combination of supervised learning and n-gram analysis. The experimental evaluation yielded an EER of 14.35% for 87 users for message blocks of 500 characters. The evaluation used real-life dataset from Enron, where the e-mails were combined to produce a single long message per individual, and then divided into smaller blocks used for authorship verification. Advanced Information Networking and Applications (ANE-2014) on 28 IEEE presented at the International Conference on the current paper, in an earlier version, feature set is expanded and Information Gain (IG) was used to rank the metric good features, also used for SVM classification. Corpus based on a data set used to evaluate experimentally. Mutual information (MI) called for an extra filter is added in the process of feature selection to take high correlation properties. SVM classification technique of the authors only, but also and SVM-LR with SVM as a hybrid method that combines research. The approach proposed two different data sets, based on a twitter feed, and other email-based Enron 140, consisting of 280 blocks and 500 characters of text are evaluated using a text message [25]. verbal elements extracted from a text (word or character) consists of a series [26]. This series of uppercase letters, lowercase letters, vowels, white space, digits, including the frequency of characters includes special characters [27], automatic recognition task, writer, author attributions, and has various practical applications for plagiarism detection. The author is a challenging area of recognition [28]. The structure of a document can be easily interpreted in the machine side. Each author's style, interpretation, natural language, is subjective general; it is more difficult to find an explanation that allows the machine to automatically tell a writer from another. Is reported in, a literature review on modern authorship attribution methods, usually coming from the fields of machine learning and statistical analysis [28,29,30,31,32]. To resolve the problem of identifying the author, with Canadian law enforcement agencies were identified in a joint project of writing analysis, three issues have been resolved [8].

A. Authorship identification with large training samples: A cybercrime investigator wants to identify the most plausible author of an anonymous text message from a group of suspects. We assume that the investigator has access to a large collection of messages that are previously written by suspects. In real-life investigation, the sample text messages can be obtained from the suspects’ e-mail archives and chat logs on the seized personal computers, or from e-mail service providers with warrants. An investigator wants to precisely extract the writing styles of each suspect from the sample messages, use such patterns to identify the author of the anonymous message, and present such patterns as evidence to support the finding. Most of the previous works on authorship identification [4,33,34,13,27] assume that every suspect has only one writing style. We argue that a person’s writing style may vary depending on the recipients or the topics. For example, when a student writes an e-mail, his writing style to a professor is probably different from his writing style to a friend. The challenge is how to precisely identify such stylistic variations and utilize the variations to further improve the accuracy of authorship identification.

B. Authorship identification with small training samples: Given a collection of anonymous messages from a group of suspects, a cybercrime investigator wants to determine the author of each anonymous message in the collection. Unlike the previous problem, this problem assumes that the investigator has access to only a few training samples written by the suspects. In real-life investigation, the investigator can ask a suspect to produce a sample of his writing by listening to a story or watching a movie, then reproducing the played scene in his own writing. Clearly, the number of samples is very limited. The major challenge is how to identify the author of the anonymous messages when there are insufficient training data to build a classifier [4,27] or to extract any significant patterns.

C. Authorship characterization: Given a collection of anonymous text messages, a cybercrime investigator sometimes has no clues about who the potential suspects are and, therefore, has no training samples of the suspects. Yet, the investigator would like to infer characteristics, such as gender, age group, and ethnic group, of the author(s) based on the writing styles in the anonymous messages. We assume the investigator has access to some external source of text messages such as blog postings and social network websites that disclose the authors’ public profiles. The challenge is how to utilize such external sources to infer characteristics of the authors of the anonymous messages.

Author identification studies, they often use the n-gram methods before learning machine. N-gram choices are important. Examples of studies in [37]. To extract the dominant character n-grams in a corpus modified the algorithm LocalMax introduced in [38]. Then, the dominant n-grams are selected according to the following rules:

\[
\text{if (C.length}>3) \]

365
\[
g(C) \geq g(\text{ant}(C)) \land g(C) \geq g(\text{succ}(C)), \text{ant}(C) \neq \text{succ}(C)
\]

In the framework of authorship identification task, only consider 3-grams, 4-grams, and 5-grams as candidate n-grams, since previous studies have shown they provide the best results [39]. To measure the glue holding the characters of a n-gram together various measures have been proposed, including specific mutual information [41], the φ2 measure [40], etc. In this study, we adopt the Symmetrical Conditional Probability (SCP) proposed in [42]. The SCP of a bigram \( |xy| \) is the product of the conditional probabilities of each given the other. A sample steps of author identification [37],

- An initial large feature set consisting of n-grams of variable length is extracted from the training corpus. This feature set includes the 1 most frequent n-grams for certain values of \( n \). That is, for \( L=5,000 \), the 5,000 most frequent 3-grams, the 5,000 most frequent 4-grams, and the 5,000 most frequent 5-grams compose the initial feature set. In some cases, the most frequent long words (length > 5) are also added to the initial feature set.

- A feature selection method is applied to this large feature set.

- A Support Vector Machine (SVM) is trained using the reduced feature set. In all experiments, linear kernels are used with \( C=1 \).

- The SVM model is applied to the test set and the micro average accuracy is calculated.

Regardless of the language by following these steps, the author identification made the process.

V. CONCLUSIONS

In this review, we have presented definitions, methods, approaches and studies about of author identification. We determined that we focus on, regardless of the language in the working document. author identification, language-dependent performance of the author’s style, the words used, the sentence structure etc. It is revealed. In studies for Turkish documents, it has 60% success rate health. We have detected that increases the weight of the working documents online.

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The effects of neighborhood strategies on the performance of Artificial Bee Colony Algorithms

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Abstract—Neighborhood topologies are extensively used in Particle Swarm Optimization (PSO). The structure of the selected topology may affect the PSO algorithm behavior. Therefore, neighborhood topology plays a crucial role on the performance of PSO algorithms when the population moves with the guidance of the best particles. However, in Artificial Bee Colony (ABC) algorithms, new population members are generated based on information exchange between the base food source and a selected member among all population. From this point of view, ABC algorithms use fully-connected neighborhood topology defined as in PSO algorithms. In this paper, we will investigate the contributions of some well-known neighborhood topologies used in PSO on the performance of ABC algorithms. We have tested fully-connected, ring, four-cluster, square and random topologies on the original ABC and global-best ABC (GABC) algorithms on the 19 benchmark functions suite (SOCO) from a special issue of the Soft Computing journal. SOCO benchmark suite consists of 7 shifted unimodal and 4 shifted multi-modal and 8 shifted hybrid functions. Experimental results reveal that population neighborhood topologies influence the performance of ABC algorithms related to the tackling problem type.

Keywords Artificial bee colony; Particle Swarm Optimization; Swarm intelligence; Single objective optimization; Neighborhood topology.

I. INTRODUCTION

Particle swarm optimization (PSO) which is a population based algorithm for global optimization, is introduced by Kennedy and Eberhart [1]. It tries to find a solution with individuals called particles.

In Standard PSO, particles communicate with each other based on social network structure called topology [2], [3]. Accordingly, each particle in the swarm can exchange information with other individuals. But some particles have information that may be useless, or some particle of information may be more important. For instance, the best-so-far particle which called as global best particle (gbest) communicates with all particles in the neighborhood structure. In literature several research have been proposed for topology structure and various type of topology structure is recommended [4], [5], [6], [7]. Neighborhood Topology has a significant impact on the performance of the algorithm [3]. For example, gbest or fully connected topology converge more quickly but it may easily trapped in a local optima [8]. On the other hand; another topology which is lbest or the ring have slow convergence speed, but it can escape from the local optima [9].

Artificial bee colony algorithm (ABC) is another population based technique [10]. ABC uses individual which is given name as food source. Neighborhood structure of food sources in ABC algorithm is similar to gbest or fully-connected topology. It means, all food sources communicate with each others. In this study, we have adopted PSO topology mechanism to original ABC and global-best ABC algorithms. We have tested fully-connected, ring, four-cluster, square and random topologies on the original ABC and global-best ABC (GABC) algorithms on the 19 benchmark functions suite (SOCO) from a special issue of the Soft Computing journal.

II. BACKGROUND

A. ABC Algorithms

1) Original Artificial Bee Colony: Artificial Bee Colony Algorithm is proposed for numerical optimization. It imitates smart behaviors of the real honey bee. According to pseudo-code of ABC which is listed in Algorithm 1, ABC has one initialization step and three repeating steps. Until a termination condition is met, Employed bees, onlooker bees and scout bees steps continue. Further details about this regarding steps are given bellow.

ABC algorithm in initialization steps which uses equation 1 to create uniformly randomly initial population of SN (SN is the number of food sources) solutions where each solution \( x_i(i = 1, 2, \ldots, SN) \) is a D-dimensional vector (D is the number of parameters).

\[
x_{ij} = x_{j}^{\min} + \text{rand}(0, 1)(x_{j}^{\max} - x_{j}^{\min})
\]

(1)

where \( i = 1, 2, \ldots, SN, j = 1, 2, \ldots, D; i \) is the index of food source and \( j \) is the index of dimension. \( x_{ij} \) represents a solution, \( x_{j}^{\min} \) is lower bound value, \( x_{j}^{\max} \) is upper bound value of the \( j \)th dimension.

In the employed bee steps, algorithm searches new promised candidate solution. By using equation 2; ABC generates new food source and evaluates its fitness value. Between old and new solution, greedy selection is applied. If the new is better than the old one, the new source position is memorized and old one is forgotten. If not, position of the old food source is kept.

\[
u_{i,j} = x_{i,j} + \phi_{i,j}(x_{i,j} - x_{r1,j}),
\]

(2)
topologies that have a different structure [5], [9], [3].

B. Neighborhood Topologies

In the PSO algorithm, each particle has social link between other particles. The set of link creates graph which is called topology of PSO. Many researchers are proposed several topologies that have a different structure [5], [9], [3].

In this study, we adopt PSO neighborhood topology mechanism to ABC algorithms. We considered popular topology structures: fully-connected, ring, square and random topologies. Their peculiarities are given below:

- **Ring Topology**: is known as local best in PSO. All node is connected to two immediate neighbor. Thus, every node has 2 neighbor. Structure of the ring topology is shown in Figure 1-a.

- **Fully-connected Topology**: is also called global best. All nodes have a link between others and get information from them. Neighbor size of fully-connected is NodeSize−1. Figure 1-b illustrates the fully-connected topology.

- **Square Topology**: which is a neighborhood topology where each node has four neighbor. Figure 1-c shows how to nodes are organized in square topology.

- **Random Topology**: creates random neighbor for all nodes. Unlike from other topology, each node has a different neighborhood structure.

![Fig. 1. Topologies which are used in this paper.](image)

### Algorithm 1: The Pseudo-code of the Original Artificial Bee Colony Algorithm

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Initialization</td>
</tr>
<tr>
<td>2.</td>
<td>Employed Bees Step</td>
</tr>
<tr>
<td>3.</td>
<td>Onlooker Bees Step</td>
</tr>
<tr>
<td>4.</td>
<td>Scout Bees Step</td>
</tr>
</tbody>
</table>

where \( i = 1, 2, \ldots, SN \), \( j = 1, 2, \ldots, D \) and \( r1 \) is a uniformly distributed random real number. \( \phi_{i,j} \) is a real number which is generated from a uniform distribution in \([-1, 1]\). \( v_{i,j} \) is the \( i \)-th solution with \( j \)-th dimension. \( x_{i,j} \) is \( j \)-th dimension of the reference food source.

In onlooker bees step, equation 2 is used same as employed bees steps to produce a new candidate solution. On the other hand, selection of a solution is based on probability of food source which is obtained by equation 3.

In ABC algorithms, food sources communicates in employed bees and onlooker bees steps. In Equation 2, a food source \( x_{r1} \) is selected randomly within the entire swarm. However, when ABC algorithms with neighborhood topologies, randomly selected food source \( x_{r1} \) is selected from neighbors of the reference food source.

GABC algorithm modifies search equation of original ABC by adding global best information and offers Equation 5 [11]. All food sources is used to determine the global best position. After we have adopted neighborhood topologies, as in original ABC algorithm, a random neighbor is determined based on neighborhood structure.

\[ v_{i,j} = x_{i,j} + \psi_{i,j}(x_{i,j} - x_{r1,j}) + \psi_{i,j}(x_{Gbest,j} - x_{r1,j}), \quad (5) \]

where \( \psi_{i,j} \) is a uniform random real in range of \([0, C]\) and \( C \) is nonnegative constant. \( x_{Gbest,j} \) is \( j \)-th element of the global best solution.

B. Neighborhood Topologies

In the PSO algorithm, each particle has social link between other particles. The set of link creates graph which is called topology of PSO. Many researchers are proposed several topologies that have a different structure [5], [9], [3].

In ABC algorithms with neighborhood mechanism, we adopt PSO neighborhood topology mechanism to ABC algorithms. We considered popular topology structures: fully-connected, ring, square and random topologies. Their peculiarities are given below:

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- **Random Topology**: creates random neighbor for all nodes. Unlike from other topology, each node has a different neighborhood structure.

![Fig. 1. Topologies which are used in this paper.](image)
IV. EXPERIMENTS

A. Benchmark Functions

To conduct experiments for the effect of the neighborhood topologies on the performance of the considered algorithms, we have used test suite of Soft Computing Special Issue on "Scalability of evolutionary algorithms and other meta-heuristics for large-scale continuous optimization problems", (SOCO) [12]. The suite has 19 problems which are separated into three categories: 1) shifted multi-modal (4 problems) 2) shifted unimodal (7 problems) 3) shifted hybrid (8 problems). For more detailed information about SOCO is listed in Table I.

B. Experimental Setup

We investigate the contributions of some well-known neighborhood topologies used in PSO on the performance of ABC algorithms. However, we have studied the question of which topology to be more efficient according to SOCO test suite.

ABC and GABC do not have too many control parameters. Parameter setting of algorithms are presented in Table II. These values are taken from [13]. Experiments are carried out with default parameter values of ABC and GABC.

Each algorithm with every topology is run for 25 times for each problems. Each run is terminated after the number of maximum function evaluations (FES) which is set as 250000. The error value can be calculated as $f(x) - f(x^*)$ where $f(x^*)$ is the optimum value of function $f$. Error values lower than $10^{-14}$ is assumed as $10^{-14}$. All results are listed are based on the mean error values in Table III and Table IV. All experiment have been conducted on 2 GB RAM and Intel Xeon E5-2620 2GHz CPU.

C. Experimental Results

In this section, contribution of four different topologies Ring, Fully-Connected, Square and Random on ABC and GABC are compared. SOCO results of four topologies adopted ABC algorithm is shown in Table III. We mark best results in bold for all problems.

When Table III is examined, it seems that there is no topology never reaches the optimum value. Random topology obtains best value of functions $f_1$, $f_2$, $f_3$, $f_4$, $f_5$, $f_7$, $f_8$, $f_9$, $f_{10}$, $f_{13}$ and $f_{14}$. Fully-connected topology is better than the others in $f_6$, $f_{11}$, $f_{17}$ and ring topology is better in $f_{12}$, $f_{15}$, $f_6$, $f_{19}$. However, square topology is not better than others for any case.

Random topology is the first who has been obtained the best value in 12 problem. Furthermore, fully-connected takes second place, ring and square gets third place.

Four topology structure is adopted to GABC and algorithm is tested with SOCO benchmark functions. Their results of mean values is illustrated in Table IV. All topologies obtain optimum value of problem $f_1$, $f_4$, $f_6$, $f_7$, $f_9$, $f_{10}$, $f_{11}$, $f_{12}$, $f_{15}$, $f_{16}$, $f_{19}$. In addition that, in $f_5$ random and fully-connected topologies also gets optimum value. Random topology acquire best value of functions $f_2$, $f_8$, $f_{17}$. In function $f_3$, $f_{13}$, $f_{18}$ Square topology and in function $f_{14}$ fully-connected achieve best value. Consequently, like as the original ABC case, random topology is superior to all other rivals for GABC.

In both algorithms, Random topology gains better results than other topologies. According to the that obtained from experiments, random neighborhood structure provide to algorithms to work more effectively. The reason for this, Random neighborhood structure contributes to exploration behavior of algorithms. Finally, the ABC and the GABC algorithm are compared with each other, GABC demonstrated superior performance according to ABC.

V. CONCLUSIONS

In this paper, four different neighborhood structures are adopted and test on original and global-best ABC algorithms. The tests have conducted on 50 dimensional SOCO test functions. The results show that overall performances of ABC algorithms with random neighborhood structure is better than others for the SOCO instances. However, for some functions other neighborhood strategies gives superior performance. As a conclusion, it is possible to say that neighborhood structures can influence the performance of the ABC algorithms directly.

For the future work, several ABC algorithms will be tested on different neighborhood strategies on other benchmark function suites such as CEC 2005, CEC 2015 and CEC 2015 test suites. On the other hand, another further work about the self-adaptation of neighborhood structure will be applied to ABC algorithms to find appropriate neighborhood structure for a given problem instance when the algorithm is running.

REFERENCES


TABLE I
DESCRIPTION OF THE SOCO BENCHMARK FUNCTION SUITE.

<table>
<thead>
<tr>
<th>Function id</th>
<th>Function name</th>
<th>Range</th>
<th>Separable</th>
<th>Uni/Multimodal</th>
</tr>
</thead>
<tbody>
<tr>
<td>f1</td>
<td>Shifted Sphere Function</td>
<td>[-100, 100]</td>
<td>Y</td>
<td>U</td>
</tr>
<tr>
<td>f2</td>
<td>Shifted Schwefels Problem 2.21</td>
<td>[-100, 100]</td>
<td>N</td>
<td>U</td>
</tr>
<tr>
<td>f3</td>
<td>Shifted Rosenbrocks Function</td>
<td>[-100, 100]</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f4</td>
<td>Shifted Rastrigins Function</td>
<td>[-5, 5]</td>
<td>Y</td>
<td>M</td>
</tr>
<tr>
<td>f5</td>
<td>Shifted Griewanks Function</td>
<td>[-600, 600]</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f6</td>
<td>Shifted Ackleys Function</td>
<td>[-32, 32]</td>
<td>Y</td>
<td>M</td>
</tr>
<tr>
<td>f7</td>
<td>Schwefels Problem 2.22</td>
<td>[-10, 10]</td>
<td>Y</td>
<td>U</td>
</tr>
<tr>
<td>f8</td>
<td>Schwefels Problem 1.2</td>
<td>[-65.536, 65.536]</td>
<td>N</td>
<td>U</td>
</tr>
<tr>
<td>f9</td>
<td>Extended f10</td>
<td>[-100, 100]</td>
<td>N</td>
<td>U</td>
</tr>
<tr>
<td>f10</td>
<td>Bohachevsky</td>
<td>[-15, 15]</td>
<td>N</td>
<td>U</td>
</tr>
<tr>
<td>f11</td>
<td>Schaffer</td>
<td>[-100, 100]</td>
<td>N</td>
<td>U</td>
</tr>
<tr>
<td>f12</td>
<td>Hybrid f9 &amp; f1 (25%, 75%)</td>
<td>[-100, 100]</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f13</td>
<td>Hybrid f9 &amp; f3 (25%, 75%)</td>
<td>[-100, 100]</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f14</td>
<td>Hybrid f9 &amp; f4 (25%, 75%)</td>
<td>[-5, 5]</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f15</td>
<td>Hybrid f10 &amp; f7 (25%, 75%)</td>
<td>[-10, 10]</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f16</td>
<td>Hybrid f9 &amp; f1 (50%, 50%)</td>
<td>[-100, 100]</td>
<td>N</td>
<td>M</td>
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<tr>
<td>f17</td>
<td>Hybrid f9 &amp; f3 (75%, 25%)</td>
<td>[-100, 100]</td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f18</td>
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<td>N</td>
<td>M</td>
</tr>
<tr>
<td>f19</td>
<td>Hybrid f10 &amp; f7 (75%, 25%)</td>
<td>[-10, 10]</td>
<td>N</td>
<td>M</td>
</tr>
</tbody>
</table>

TABLE II
PARAMETERS SETTING OF THE ALGORITHMS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>ABC</th>
<th>GABC</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>62</td>
<td>15</td>
<td>Population size</td>
</tr>
<tr>
<td>lf</td>
<td>1</td>
<td>1</td>
<td>The limit factor</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>1</td>
<td>Maximum range value which is used by GABC</td>
</tr>
</tbody>
</table>

### TABLE III

Given are mean function values of ABC with topology for each functions of dimension 50 from the SOCO benchmark set.

<table>
<thead>
<tr>
<th>Function ID</th>
<th>Fully-connected</th>
<th>Random</th>
<th>Ring</th>
<th>Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>f1</td>
<td>1.400E-11</td>
<td>1.119E-11</td>
<td>1.681E-10</td>
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**Rank**: 2 1 4 3

---


TABLE IV

Given are mean function values of GABC with topology for each functions of dimension 50 from the SOCO benchmark set. The values in parenthesis are the average number of function evaluations to reach optimum value.

<table>
<thead>
<tr>
<th>Function ID</th>
<th>Fully-connected</th>
<th>Random</th>
<th>Ring</th>
<th>Square</th>
</tr>
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<tbody>
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<td>1.000E-14 (44842)</td>
<td>1.000E-14 (46014)</td>
<td>1.000E-14 (47702)</td>
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<tr>
<td>f2</td>
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<td>1.915E+00</td>
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<tr>
<td>f3</td>
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<td>1.954E+01</td>
<td>1.004E+01</td>
</tr>
<tr>
<td>f4</td>
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<td>1.000E-14 (69751)</td>
<td>1.000E-14 (70416)</td>
<td>1.000E-14 (97542)</td>
</tr>
<tr>
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<tr>
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<td>1.000E-14 (70475)</td>
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</tr>
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Rank | 3 | 1 | 4 | 2
A Detailed Analysis of Optical Character Recognition Technology

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Abstract—In many different fields, there is a high demand for storing information to a computer storage disk from the data available in printed or handwritten documents or images to later re-utilize this information by means of computers. One simple way to store information to a computer system from these printed documents could be first to scan the documents and then store them as image files. But to re-utilize this information, it would very difficult to read or query text or other information from these image files. Therefore a technique to automatically retrieve and store information, in particular text, from image files is needed. Optical character recognition is an active research area that attempts to develop a computer system with the ability to extract and process text from images automatically. The objective of OCR is to achieve modification or conversion of any form of text or text-containing documents such as handwritten text, printed or scanned text images, into an editable digital format for deeper and further processing. Therefore, OCR enables a machine to automatically recognize text in such documents. Some major challenges need to be recognized and handled in order to achieve a successful automation. The font characteristics of the characters in paper documents and quality of images are only some of the recent challenges. Due to these challenges, characters sometimes may not be recognized correctly by computer system. In this paper we investigate OCR in three different ways. We first review the general phases of an OCR system such as pre-processing, segmentation, normalization, feature extraction, classification and post-processing. Then, we give a detailed overview of the challenges that might emerge in these OCR stages. Finally, we highlight development and main applications and uses of OCR. Therefore, this discussion provides a very comprehensive review of the state-of-the-art of the field.

Keywords—OCR; OCR Challenges; OCR Phases; OCR Applications

I. INTRODUCTION

Optical character recognition is an active research area that attempts to develop a computer system with the ability to extract and process text from images automatically. These days there is a huge demand for storing information to a computer storage disk from the data available in printed or handwritten documents to later re-utilize this information by means of computers. One simple way to store information to computer system from these paper documents could be to first scan the documents and then store them as image files. But to re-utilize this information, it would very difficult to read or query text or other information from these image files. Therefore a technique to automatically retrieve and store information, in particular text, from image files is needed. Of course, this is not a very trivial task. Some major challenges need to be laid out and handled in order to achieve a successful automation. The font characteristics of the characters in paper documents and quality of images are only some of the recent challenges. Due to these challenges, characters sometimes may not be recognized correctly by computer system. Thus there is a need of mechanisms of character recognition to perform Document Image Analysis (DIA) which overcomes these challenges and produces electronic format from the transformed documents in paper format.

Similarly, Optical Character Recognition (OCR) is the process of modification or conversion of any form of text or text-containing documents such as handwritten text, printed or scanned text images, into an editable digital format for deeper and further processing. Optical character recognition technology enables a machine to automatically recognize text in such documents. In real world example, it is like combination of mind and eye of human body. An eye can detect, view and extract the text from the images but absolutely the human’s brain processes that detected or extracted text read by eye [1]. Of course OCR technology has not advanced enough to compete with human’s ability. The performance and accuracy of OCR is directly dependent upon the quality of input documents. Again, when we think of human’s ability to recognize text, the performance of brain’s process directly depends upon the quality of the input read by eye.

Today, to solve the text recognition problem several different types of OCR software exist such as Desktop OCR, Server OCR, web OCR and so on. Since the OCR research is an active and important field in general pattern recognition problems, due to its fast progress, comprehensive reviews of the field are needed on a regular basis to keep track of the new advancements. One such review was published to discuss the challenges with text recognition in scene imagery [2]. This paper attempts to elaborate on these kinds of studies by providing a comprehensive literature review of optical character recognition research. We discuss major challenges
and main phases of optical character recognition such us pre-
processing, segmentation, normalization, feature extraction,
classification and post processing in detail which needs to be
considered during implementing any application related to the
OCR, and in the last section of our paper some OCR
applications are discussed.

II. OCR CHALLENGES

For good quality and high accuracy character recognition,
OCR techniques expect high quality or high resolution images
with some basic structural properties such as high
differentiating text and background. The way images are
generated is an important and determining factor in the
accuracy and success of OCR, since this often affects the
quality of images dramatically. Usually OCR with images
produced by scanners gives high accuracy and good
performance. In contrast, images produced by cameras usually
are not as good as an input as scanned images to be used for
OCR due to the environmental or camera related factors.
Numerous errors might emerge, which are clarified as follow.

A. Scene Complexity

In a regular environment, we can see large numbers of
man-made objects which are included in camera taken images
such as paintings, buildings, and symbols. These objects have
comparative structures and appearances to text which makes
text recognition very challenging in the processed image. Text
itself is regularly laid out to encourage decipherability. The
challenge with scene intricacy is that the surrounding scene
makes it hard to segregate text from non-text [2].

B. Conditions of Uneven Lighting

Oftentimes, taking images in natural environments results
in uneven lighting and shadows. This poses a challenge for
OCR as it degrades the desired characteristics of the image
and hence causes less accurate detection, segmentation and
recognition results [2].

This condition with uneven lighting is what distinguishes a
scanned image form one that is produced with a camera. The
lack of such disparities in lighting and shadows makes scanned images preferred over camera images for their better
characteristics and quality. Although using an on-camera flash
may eliminate such problems with uneven lighting, it
introduces new challenges.

C. Skewness (Rotation)

For optical character recognition systems, the point of
view for the input image that taken from camera of hand-held
device or other gadgets that used for taken image is not fixed
like a scanner input, which skewing of text lines from their
unique orientation might be observed. Great degree poor
results will be observed when such a skewed image is fed to
the OCR classifier. Many techniques available for the purpose
development the image documents, such as Projection Profile,
RAST algorithm, Hough transform, methods of Fourier
transformation, etc.

D. Blurring and Degradation

Since working over a variety of distances are intended to
numerous digital cameras, an important factor is the digital
camera’s focusing. For the best accuracy of character
recognition and character segmentation, character sharpness is
required. At large apertures and short distances, uneven focus
can be observed when a small point of view changes. For the
most part connected with photography, there are two kinds of
obscure which is: out of focus obscure and movement obscure
[3]. At the point for catching a moving item, when the shade
rate of the camera is not sufficiently high, the sensor gets
presented to a continually changing scene. Accordingly,
blurring will observed in parts in motion.

E. Aspect Ratios

Text has different aspect ratios. Text may be brief such as
traffic signs, while other text may be much longer, such as
video captions. Location, scale and length of text need to be
considered with search procedure to detect text, which
introduces high computational complexity.

F. Tilting (Perspective Distortion)

Document images obtained by scanners is constantly
parallel to the plane of sensor, but this cannot be observed all
times for recorded picture obtained by a portable camera, that
may not generally be parallel to the form plane. Accordingly,
lines of text that distant from the camera seem littler than
those that nearer to the camera which seems greater. This
situation causes tilted pictures. Observation of a perspective
distortion is clear if the recognizer is not perspective intolerant,
which causes lower recognition rate and accuracy [4].

Cell phones have an advantage with orientation sensors.
They can recognize whether the device is tilted and when
twisting happens they can forbid clients to take pictures.
Permitting the user to align plane of the form with that of the
camera is also provided by this feature. Orientation sensors
therefore may assure that produced pictures satisfy a certain
degree of evenness.

G. Fonts

Italic style and script fonts of characters might overlap each
other, making it difficult to perform some of the main OCR
processes such as segmentation. Characters of various fonts
have large within-class variations and form many pattern sub-
spaces, making it difficult to perform accurate recognition
when the character class number is large.

H. Multilingual Environments

Although most of the Latin languages have tens of
characters, languages such as Chinese, Japanese and Korean,
have thousands of character classes. Arabic has connected
characters, which change shape according to context. In Hindi
syllables represent by combining alphabetic letters into
thousands of shapes [5]. In multilingual environments, OCR
in scanned documents remains as a main research problem [5],
since text recognition in complex imagery is more difficult.
I. Warping

Content or text on objects of varying geometries can be another challenge for OCR to be recognized when images of such situation captured by hand-held cameras. A few circumstances may emerge with flatted scanners, wherein the twisted text observed when the content procured on picture, for example the content towards the binding of an extremely thick book.

For convention paper documents, a technique for image dewarping is proposed by Ulges et al. [6]. By expecting the way that content lines are equally separated and parallel to each other, they dewarp pictures.

III. OCR PHASES

In this section we describe the main important phases and architecture of optical character recognition. These phases include pre-processing, segmentation, normalization, future extraction, classification and post processing. For designing an effective application related to the OCR, we must be considering the difficulties that may arise in each phase to obtain high character recognition rate.

A. Pre-processing Phase

The aim of pre-processing is to eliminate undesired characteristics or noise in an image without missing any significant information. Preprocessing techniques are needed on color, grey-level or binary document images containing text and/or graphics. Since processing color images is computationally more expensive, most of the applications in character recognition systems utilize binary or grey images. Preprocessing reduces the inconsistent data and noise. It enhances the image and prepares it for the next phases in OCR phases.

Thus, since preprocessing controls the suitability of the input for the successive phases, a primary stage prior to feature extraction phase is the pre-processing phase. Most of the challenges we listed in OCR Challenges’ section need to be addressed in preprocessing stage. Some operations that we may consider to carry out can be listed as follows: binarization, noise reduction, skew correction, morphological operations, slant removal, filtering, thresholding, smoothing, compression, and thinning. Some important preprocessing issues with short description were illustrated in Table I.

<table>
<thead>
<tr>
<th>Processes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Binarization</td>
<td>Separates image pixels as text or background.</td>
</tr>
<tr>
<td>Noise Reduction</td>
<td>Better improvements of image acquisition devices produced by the advancements in technology.</td>
</tr>
<tr>
<td>Skew Correction</td>
<td>Because of the possibility of rotation of the input image through captured image device, document skew should be corrected.</td>
</tr>
<tr>
<td>Morphological</td>
<td>Adding or removing pixels to the characters</td>
</tr>
</tbody>
</table>

B. Segmentation Phase

The critical and major component of an Optical Character Recognition (OCR) system is the segmentation of text line from images. In general, Text segmentation from a document image merges line segmentation, word segmentation and then character segmentation. Segmentation is the process of isolating text component within an image from the image’s background. For appropriate reorganization of the editable text lines from the recognized characters, firstly, segmenting the line of text, then the words are segmented from the segmented line and then from that the characters are segmented.

Document segmentation is a major pre-processing phase in implementing an OCR system. It is the process of classifying a document image into homogeneous zones, i.e., that each zone contains only one kind of information, such as text, a figure, a table, or a halftone image. In many cases, the accuracy rate of systems related to the OCR heavily depends on the accuracy of the page segmentation algorithm used.

There are three categories of Algorithms of document segmentation [7] As follows:

- Top-down methods,
- Bottom-up methods,
- Hybrid methods.

The top-down approach in a document segments large regions into smaller sub regions recursively. When criterion is met then the document segmentation process will stop and at that stage the ranges obtained constitute the results of final segmentation. But, approaches of bottom-up start by searching for interest pixels and then groups interest pixels. They then manage those interest pixels into connected components that constitute characters which are then combined into words, and lines or text blocks. The integration of both top-down and bottom-up methods is called hybrid approaches.

Regarding different aspects of OCR system throughout the last decades many approaches have already been proposed for segmentation.

A novel technique for Text Segmentation based on A Hough Transform, was proposed by Satadal Saha, Subhadip Basu, Mita Nasipuri and Dipak Kr. Basu [8].

Extracting Text line from multi skewed handwritten document images has been studied by S. Basu et al [9]. The proposed technique for extraction of text lines implements a water flow technique with high rate of success.

A. Khandelwal et al [10] proposed a technique by comparing neighborhood connected components on text line segmentation from unconstrained handwritten document images.

Shinde, Archana A., and D. G. Chougule also proposed a segmentation technique in their paper [11]. They presented...
that utilizing the traditional vertical and horizontal projection profile method makes text easily segmented into lines and words. They reported experimental results with 98% accuracy of line and word segmentation.

C. Normalization Phase

As a result of segmentation process isolated characters which are ready to move through feature extraction phase are obtained, hence the isolated characters are minimized to a particular size depending on the algorithms used. The segmentation process is crucial as it converts the image in the form of m*n matrix. These matrices are then commonly normalized by minimizing the size and eliminating the unnecessary information from the image without missing any influential information [12].

D. Feature Extraction Phase

Feature extraction is the operation of extracting the pertinent features from objects or alphabets to build feature vectors. These feature vectors are then utilized by classifiers to identify the input unit with objective output unit. It becomes effortless for the classifier to classify between dissimilar classes by glancing at these features as it becomes fairly easy to determine [13].

Several techniques are proposed for extracting features from the segmented characters in literature. U. Pal et al [14] have proposed directional chain code features and zoning and for handwritten numeral recognition considered a feature vector of length 100 and have presented a high level of recognition accuracy. But, the feature extraction process is time consuming and complex [13].

Dinesh et al [15] have proposed end points as the potential features for recognition and used horizontal/vertical strokes and for handwritten Kannada numerals obtained a recognition accuracy of 90.50%. But, this method uses the thinning process which results in some loss of features [13].

E. Srinivasan et al [13] for handwritten alphabets recognition system have proposed diagonal based feature extraction utilizing neural network.

Sharma, Om Prakash et al [16] for handwritten alphabets recognition proposed an improved zone based hybrid feature extraction model utilizing Euler number.

Following to Sue [17], there are two major classes of features: statistical features and structural features. In a character matrix statistical features are obtained from statistical distribution of every point such as zoning, moments, crossings, fourier transforms and projection histograms [18]. Statistical features are also notable as global features as they are usually averaged and extracted in sub-images such as meshes. Initially, statistical features are supplied to recognize machine printed characters. On the other hand, structural or topological features are concern to the geometry of the character set to be contemplated. Some of these features are convexities and concavities in the characters, number of holes in the characters, number of end points etc.

E. Classification Phase

OCR systems broadly utilize the methodologies of pattern recognition, which assigns each example to a predefined class. Classification is the procedure of distributing inputs with respect to detected information to their comparing class in order to create groups with homogeneous qualities, while segregating different inputs into different classes. Classification is conveyed out on the premise of put away features in the feature space, for example, structural features, global features and so forth. It can be said that classification isolates the feature space into several classes taking into account the decision rule. Choosing classifier depends on several agents, such as, number of free parameters, available training set and so forth. Various procedures for OCR are explored by the scientists.

Techniques of OCR classification can be categorized [19] as Statistical Techniques, Neural Networks, Template Matching, Support Vector Machine (SVM) algorithms, and Combination of classifier.

1) Template matching: This is the least complex method for character recognition, in view of matching the stored models against the word or character to be perceived. By gathering of shapes, pixels, curvature and so forth, the operation of matching decides the level of similitude between two vectors. A gray-level or binary input character is contrasted with a standard arrangement of stored models. The recognition rate of this strategy is extremely delicate to noise and input disfigurment.

2) Statistical Techniques: Hypothesis of Statistical decision is treating with statistical decision capacities and an arrangement of optimality criteria, which for a given model of a specific class can amplify the likelihood of the observed pattern. The main statistical methods that are performed in the area of OCR are Nearest Neighbor (NN), Likelihood or Bayes classifier, Clustering Analysis, Hidden Markov Modelling (HMM), Fuzzy Set Reasoning, and Quadratic classifier.

3) Neural Networks: Character classification issue is identified with heuristic rationale as people can perceive characters and records by their learning and experience. Thus neural networks which are pretty much heuristic in nature are greatly appropriate for this type of issue [19]. A neural network is an ascertaining architecture that includes enormously parallel interconnection of flexible node processors. Output from one node is reinforcing to the next one in the network and an official choice relies on the complicated collaboration of all nodes. As a result of its similar character, it can apply calculations at a rate higher contrasted with the traditional strategies. Feed-forward neural networks and feedback neural networks can be thought as categorization of neural network architectures. Table II, compares and discusses some recent proposed OCR applications based on Neural Network.

<table>
<thead>
<tr>
<th>TABLE III</th>
<th>ACCURACY COMPARISON AMONG RECENT PROPOSED OCR SYSTEMS BASED ON NEURAL NETWORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>OCR Application</td>
</tr>
</tbody>
</table>

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4) **Kernel Methods**: While the most imperative kernel strategies are support Vector Machines, techniques such as Kernel Fisher Discriminant Analysis (KFDA) and Kernel Principal Component Analysis (KPCA) also employ kernel method. Support vector machines (SVM) are one of the most widely used and most effective supervised learning techniques that can be used for binary or multi-class classification. In classification techniques, by convention the data set first is partitioned into training and testing sets. The objective of SVM is to deliver a model, which predicts the output of the test set [24]. Width of the edge between the classes is the enhancement rule, i.e., the unfilled zone around the decision boundary characterized by the interval to the closest training example [25].

5) **Combination Classifier**: Different classification strategies have their own particular advantages and shortcomings. Thus ordinarily various classifiers are consolidated together to solve a given classification problem. Matei, Olivia, Petrica C. Pop, and H. Vălean [26] by utilizing neural networks and k-Nearest Neighbor, proposed Optical character recognition in real environments such as electricity-meters and gas-meters.

**F. Postprocessing Phase**

It has been shown that people can read handwriting by context up to 60%. While preprocessing tries to clean the record in a specific sense, it might evacuate critical data, since the context data is not accessible at this stage. On the off chance that the semantic data were accessible to a specific degree, it would contribute a considerable measure to the precision of the OCR stages. On the other hand, the whole OCR issue is for deciding the context of the saved image. In this way the incorporation of context and shape data in all the phases of OCR frameworks is vital for meaningful upgrades in recognition rates. This is done in the Postprocessing stage with an input to the early phases of OCR. The least complex method for consolidating the context data is the usage of a dictionary for amending the minor errors of the OCR frameworks. The fundamental thought is to spell check the OCR yield and give a few distinct options for the yields of the recognizer that take place in the dictionary.

**IV. OCR APPLICATIONS**

Optical character recognition has been performed in a numerous of applications. We discussed some of these application areas in this section.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhai, Xiaojun, et al [21]</td>
<td>Automatic Number Plate Recognition ANPR</td>
<td>97.3</td>
</tr>
<tr>
<td>Shamsher, Inam, et al [22]</td>
<td>OCR for printed Urdu script</td>
<td>98.3</td>
</tr>
<tr>
<td>Yetirajam, Manas, et al [23]</td>
<td>classification and Recognition of broken characters</td>
<td>68.33</td>
</tr>
</tbody>
</table>

**A. Handwriting Recognition**

Handwriting recognition is the capacity of a PC to get and translate intelligible handwritten data from sources, for example, paper records, photos, touch-screens and different gadgets.

**B. Receipt Imaging**

Receipt imaging [27] is broadly utilized as a part of numerous organizations applications to monitor financial records and keep accumulation of payments from heaping up. In government offices and autonomous organizations, OCR simplifies information gathering and analysis, among different procedures.

**C. Legal Industry**

Legal industry [27] is likewise one of the recipients of the OCR innovation. OCR is utilized to digitize documents, and to specifically enter into PC database. Legitimate experts can further search documents required from tremendous databases by basically writing a few keywords.

**D. Banking**

Another imperative use of OCR is in banking [27], where it is utilized to process cheques without human intervention. A cheque can be embedded with a machine where the framework filters the sum to be issued and the right measure of cash is exchanged. This innovation has been idealized for printed cheque, and is genuinely precise for handwritten checks diminishing the hold-up time in banks.

**E. Healthcare**

To process printed material, medicinal services [27] have likewise seen an expansion in the utilization of OCR innovation. Medicinal service experts continuously need to manage extensive volumes of documents for each patient, including protection frames and in addition general health forms. To stay aware of every one of this data, it is valuable to input relevant information into an electronic database. With OCR processing tools, we can extract data from structures and put it into databases, so that each patient's information is quickly recorded and retrieved when needed in future.

**F. Captcha**

A CAPTCHA [28] is a system that can create and grade tests that human can pass yet current software technology can't. Malicious programmer can make software to misuse personal information on websites. Dictionary attack is assault against secret word confirmed frameworks where a programmer composes a system to over and over attempt distinctive passwords like from dictionary of most regular passwords. In CAPTCHA, a picture comprising an arrangement of letters and numbers is produced with variety of size and textual styles, distracting backgrounds, arbitrary portions, highlights and noise so that text cannot be read via OCR. Current OCR frameworks can be utilized to evacuate the noise and portion the picture to make the picture tractable by such malicious users.
G. Automatic Number Plate Recognition

Automatic number plate recognition [29] is utilized as a mass observation method making utilization of optical character recognition on pictures to recognize vehicle registration plates. ANPR has additionally been made to store the pictures caught by the cameras including the numbers caught from license plate. ANPR innovation own to plate variety from place to place as it is an area particular innovation. They are utilized by different police forces and as a technique for electronic toll accumulation on pay-per-use streets.

V. CONCLUSIONS

Numerous algorithms, methods and techniques have been proposed to optical character recognition in scene imagery, yet there are not enough literature surveys in this field. In this paper, we have proposed an organization of these methods, algorithms and techniques. It is hoped that this comprehensive survey will provide insight into the concepts involved, and perhaps provoke further advances in the area. Firstly, we discussed major challenges of OCR, then we discussed in great detail the main important phases, architecture, proposed algorithms and techniques of OCR, we highlight that for designing any application related to the OCR, one must pay great attention to each phase to obtain high accurate character recognition rate, but still we cannot propose comprehensive algorithms for each phase because it depends upon datasets, application specifics, and parameter specifics. Finally major applications related to the OCR are discussed.

Although the state-of-the-art OCR enables text recognition with high accuracy, we think that there could be many more practical applications of OCR. As a future work we are planning to use OCR for such practical applications for daily personal use. We are planning to incorporate mobile devices with OCR in one OCR system. An automated book reader or a receipt trader constitutes some of our future OCR based applications.

REFERENCES

An Analysis on the Comparison of the Performance and Configuration Features of Big Data Tools Solr and Elasticsearch

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Abstract—Today, every kind of text, audio and visual data, which are thought to be transformed into pieces of information, are stored for long periods of time for processing. The concept of Big Data is not only associated with the data stored, but also with the system involving hardware and software that collects, processes, stores, and analyzes the data. As the data grows bigger, their physical storage options must be provided in a distributed architecture.

Solr and Elasticsearch are among the most preferred tools which makes this storage process easier. As a part of Apache Lucene project, Solr is a software which was started to be developed in 2004 with the searching features of full text, multiple search, dynamic clustering, database-integrated, open source and elasticity. Similarly, Elasticsearch is a new open-source tool for real-time, full-text and distributed search, which was launched in 2010 using the Lucene library. Although Solr and Elasticsearch have similar features, there are many parameters that differentiates one from the other such as intended use, type of use, and query and indexing performances. This study researches and analyzes the differences between Solr and Elasticsearch with regards to their query and indexing speeds, ease and difficulties of use, configuration forms, and architectures in light of the literature, and the results are discussed regarding these tools’ performances.

Keywords—big data, elasticsearch, solr

I. INTRODUCTION

Huge amount of data stack which cannot be stored nor processed by traditional methods is called Big Data [1]. Based on the fact that most of the smart devices communicate on the Internet and the technological devices and computers will communicate through cloud computing, it is easy to predict that much bigger data is to be produced in the future [2]. It is impossible to store, process, and analysis this big data by conventional tools. Therefore, many tools were developed for the data which can be regarded as Big Data. It was observed that Big Data tools and techniques that are used in processing this data provided better performance results in comparison with traditional tools and techniques [3].

One of these tools is Solr which is an open source, Java-based tools that uses Apache Lucene search library and it can be used on servers such as Tomcat, Jetty, etc. [4]. According to July, 2016 figures of DB-Engines Ranking of Search Engines, Solr is the second most popular search engine software [5]. With its 5th version, Solr has become a separate software instead of being a Java package [6].

Elasticsearch is one of the other tools that is used in analyzing and process Big Data. It is an open-source, Lucene-based content search and analysis tool that was developed in Java. This tool, which began to be developed in 2010, is used by many domestic/foreign organizations. It is also a tool that can be set up in Cloud servers purchased through Google For Works, and it is in a sense supported by Google [7]. According to July, 2016 figures of DB-Engines Ranking of Search Engines, Elasticsearch is the most popular search engine software [5].

Because of the fact that both of Solr and Elasticsearch tools are based on Apache Lucene library, and they have similarities between the intended use and methods, supported protocols, and coding languages, today they are compared and contrasted by users in different categories. Users try to decide which one is the best tool for them based on their own needs and system requirements.

This study, therefore, collects comparative data conducted so far between Solr and Elasticsearch. These collections involve technical configurations, performance tests, etc. This study is thought to contribute to software developers in using Solr and Elasticsearch.
II. SOLR

Solr is an open source enterprise search platform, written in Java, from the Apache Lucene project and its major features include full-text search, hit highlighting, faceted search, real-time indexing, dynamic clustering, database integration, NoSQL features and rich document (e.g., Word, PDF) handling [6][8].

A. Technical Specifications of Solr

Each data in Solr is named as Document. A simple analogy between Solr and Java Database is as follows:

- Java Class = Solr Document
- Java Class Attribute = Document Field
- Database table = Solr Document
- Column in the database table = Document Field

A Solr Document can be generated by method of creating a table in a database or building a Java class.

Data indexed by Solr provides a fast response based on query type through Request method on HTTP. In addition that query results can be instantly listed on the screen, one can also print out in XML, JSON, CSV, etc. formats.

Solr uses Lucene library in indexing, analyzing, and searching processes, which involves filtering on existing structures, faceting, caching, and distributed architecture support. While Solr can be used as an API server similar to REST, it can also operate on protocols that are supported by HTTP/XML or JSON coding languages. Additionally, it supports libraries that work independently in Java and enables specifications.

Rules regarding the Documents designed in Solr are stored in Schema.xml file. There are <field> settings in Schema file which corresponds to “column” in traditional databases. These settings are composed of the parameters of field name, whether it is indexed in Solr search, whether it is stored and responds to findings, whether it is multi-valued, and what type of data it includes [9].

A sample schema file involves the following data:

```xml
<field name="id" type="string" indexed="true" stored="true" required="true" multiValued="false"/>
<field name="sku" type="text_en_splitting_tight" indexed="true" stored="true" omitNorms="true"/>
<field name="name" type="text_general" indexed="true" stored="true"/>
<field name="manu" type="text_general" indexed="true" stored="true" omitNorms="true"/>
```

B. How to Use Solr

After the installation of Solr, some sample data sets in “exampledocs” file can be used. A sample data file is as follows:

<table>
<thead>
<tr>
<th>TABLE I</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE DOCUMENT</td>
</tr>
<tr>
<td>TWINX2048-3200PRO</td>
</tr>
<tr>
<td>CORSAIR XMS 2GB (2 x 1GB) 184-Pin DDR SDRAM</td>
</tr>
<tr>
<td>Unbuffered</td>
</tr>
<tr>
<td>Corsair Microsystems Inc.</td>
</tr>
<tr>
<td>corsair electronics</td>
</tr>
<tr>
<td>memory</td>
</tr>
<tr>
<td>CAS latency 2, 2-3-3-6 timing, 2.75v</td>
</tr>
<tr>
<td>185</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>true</td>
</tr>
<tr>
<td>37.7752,-122.4232</td>
</tr>
<tr>
<td>2006-02-13T15:26:37Z</td>
</tr>
<tr>
<td>electronics</td>
</tr>
</tbody>
</table>

| VS1GB400C3 |
| CORSAIR ValueSelect 1GB 184-Pin |
| Corsair Microsystems Inc. |
| corsair electronics |
| memory |
| 74.99 |
| 7 |
| true |
| 37.7752,-100.0232 |
| 2006-02-13T15:26:37Z |
| electronics|4.0 memory|2.0 |

Data in Table 1 can be listed by the following methods on sonar browser after indexed in Solr.

Request:

```
http://localhost:8983/solr/select?q=*:*&wt=json
```

- Lists all data
- wt=json Listed in JSON format

Request:

```
http://localhost:8983/solr/select?q=id:VS1GB400C3&wt=json &fl=id,name
```

- Lists data with VS1GB400C3 id parameter value
- wt=json Listed in JSON format
- fl=id,name Lists only id and name information in results page.
III. ELASTICSEARCH

Elasticsearch is also another distributed and open-source analysis and search tool which was developed using Lucene library. It was designed for Scalability, security, and easy management. By means of its query language that indexes structural and non-structural, and time-based data, provides rapid search and powerful analysis capabilities.

A. Technical Specifications of Elasticsearch

Elasticsearch is a document-based tool. Each entry in Elasticsearch is a structured JSON document. In other words, each data sent to Elasticsearch for indexing is a JSON document [10]. It is necessary to know some basic concepts to understand the structure of Elasticsearch. These are as follows:

Index: An index is like a database in a relational database. Each Elasticsearch index is a structured JSON document.

Type: A type is like a table in a relational database. Elasticsearch indexes can include more than one type.

Mapping: This is the process of managing how the data transferred types on indexes should be handled. It is equal to identification of data type (string, integer, double, boolean) before adding the data in the traditional databases. Elasticsearch automatically realizes mapping based on the data, and however this can also be done manually.

Shard/Sharding: It is the horizontal distributing of data to other machines on the network in database technologies. Thanks to sharding technology, data can be divided into pieces based on the existing physical facilities. Elasticsearch divides indexes into 5 shards by default to store them.

Replica: A replica is a copy of the primary shard. It is mainly used to prevent data loss in index documents as well as to distribute the load of the indexes in distributed database architectures. Elasticsearch indexes creates one copy of each shard document when they are created at first.

Schema: Being schema-free, Elasticsearch automatically realizes index, type, filed type descriptions and does not require the users to do so.

Elasticsearch can be managed by JSON commands over HTTP with RESTful API. Thereby, it can operate on many coding languages with no problem.

B. How to Use Elasticsearch

Elasticsearch can be used in computers with JVM installed after downloading. It does not require configuration for first use. Data adding/query can be conducted on curl (client URL library) as it is for RESTful API.

---

TABLE II

SAMPLE OF ADDING DATA

mustafa:~ mustafa$ curl -XPUT localhost:9200/deneme/article/1 -d '>
> {>
> title: "ElasticSearch",
> content: "ElasticSearch is developed in Java, open-source, lucene-based, scalable full-text search engine and data analysis tool.",
> date: "2016-07-07T12:00:00",
> author: "Mustafa Ali AKCA"
> }

{"ok":true,"_index":"deneme","_type":"article","_id":"1","_version":1}

Through commands shown in Table II, type 1 id data named “article” found in “deneme” index was added. Command and query result in order to query this command is shown in Table III.

TABLE III

QUERY SAMPLE

mustafa:~ mustafa$ curl -XGET localhost:9200/deneme/article/1?pretty=true

{ "_index" : "deneme",
  "_type" : "article",
  "_id" : "1",
  "_version" : 1,
  "exists" : true,
  "_source" :
    { "title" : "ElasticSearch",
      content: "ElasticSearch is developed in Java, open-source, lucene-based, scalable full-text search engine and data analysis tool.",
      date: "2016-07-07T12:00:00",
      author: "Mustafa Ali AKCA"
    }
}

While using Elasticsearch indexes, curl library can be used in addition to “Sense” plugin in Google Chrome.

Elasticsearch provides client support for many platforms including Java, Ruby, PHP, Python and .NET, and it can be managed through coding languages of these platforms.
IV. TECHNICAL COMPARISON BETWEEN SOLR AND ELASTICSEARCH

A. Overview
Table IV provides a general overview for the features of Solr and Elasticsearch tools.

<table>
<thead>
<tr>
<th>TABLE IV</th>
<th>OVERVIEW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solr</strong></td>
<td><strong>Elasticsearch</strong></td>
</tr>
<tr>
<td>Initial Release</td>
<td>2004</td>
</tr>
<tr>
<td>Current Release</td>
<td>6.1.0 June 2016</td>
</tr>
<tr>
<td>Licence</td>
<td>Open Source</td>
</tr>
<tr>
<td>Database as a Service</td>
<td>No</td>
</tr>
<tr>
<td>SQL</td>
<td>No</td>
</tr>
<tr>
<td>Implementation language</td>
<td>Java</td>
</tr>
<tr>
<td>Server operating systems based</td>
<td>All OS with a Java VM and a servlet container (Tomcat, Jetty, etc)</td>
</tr>
<tr>
<td>Admin Interface</td>
<td>Apache Lucene</td>
</tr>
<tr>
<td>Embedded Available</td>
<td>Plugin Needed (Bigdesk, Kopf, ElasticHQ, Paramedic, Marvel, etc)</td>
</tr>
</tbody>
</table>

B. Access and Data Processing
Detailed data can be found in Table V regarding the comparison between Solr and Elasticsearch based on their data processing methods and direct or indirect access.

<table>
<thead>
<tr>
<th>TABLE V</th>
<th>ACCESS AND DATA PROCESSING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solr</strong></td>
<td><strong>Elasticsearch</strong></td>
</tr>
<tr>
<td>Access Methods</td>
<td>RESTful http API, Java API</td>
</tr>
<tr>
<td>Supported client language</td>
<td>.Net, Erlang, Java, JavaScript (XML or JSON), Perl, PHP, Python, RubyScala</td>
</tr>
<tr>
<td>Data Import</td>
<td>JDBC, MySQL, CSV, XML, Tika, URL, Flat File</td>
</tr>
</tbody>
</table>

C. Data and Distributed Architecture
Data storage, data processing, and distributed architecture features of Lucene-based Solr and Elasticsearch are found in Table VI.

<table>
<thead>
<tr>
<th>TABLE VI</th>
<th>DATA AND DISTRIBUTED ARCHITECTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solr</strong></td>
<td><strong>Elasticsearch</strong></td>
</tr>
<tr>
<td>Distributed Architecture</td>
<td>Supports</td>
</tr>
<tr>
<td>Sharding</td>
<td>Yes</td>
</tr>
<tr>
<td>Replication</td>
<td>Yes</td>
</tr>
<tr>
<td>Shard Splitting</td>
<td>Yes</td>
</tr>
<tr>
<td>Changing Number of Shards</td>
<td>Yes</td>
</tr>
<tr>
<td>Relocating</td>
<td>Yes</td>
</tr>
<tr>
<td>Routing</td>
<td>Yes</td>
</tr>
<tr>
<td>Schematic</td>
<td>Yes (After 4.4)</td>
</tr>
<tr>
<td>Map Reduce</td>
<td>No</td>
</tr>
<tr>
<td>Automatic Shard Rebalancing</td>
<td>No</td>
</tr>
<tr>
<td>Distributed Group By</td>
<td>Yes</td>
</tr>
</tbody>
</table>

D. Searching and Indexing
Solr and Elasticsearch have different indexing and searching features based on their basic structures and the plugins developed by users (see Table VII).

<table>
<thead>
<tr>
<th>TABLE VII</th>
<th>SEARCHING AND INDEXING [11]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solr</strong></td>
<td><strong>Elasticsearch</strong></td>
</tr>
<tr>
<td>Custom Analyzers and Tokenizers</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiple Indexes</td>
<td>Yes</td>
</tr>
<tr>
<td>Realtime Search/Indexing</td>
<td>Yes</td>
</tr>
<tr>
<td>Multiple document types per schema</td>
<td>No</td>
</tr>
<tr>
<td>Schema Changes</td>
<td>Yes</td>
</tr>
<tr>
<td>Field Copying</td>
<td>Yes</td>
</tr>
<tr>
<td>Distributed Search</td>
<td>After 2012</td>
</tr>
<tr>
<td>Term Vectors API</td>
<td>Yes</td>
</tr>
<tr>
<td>Autocomplete</td>
<td>Yes</td>
</tr>
<tr>
<td>Highlighting</td>
<td>Yes</td>
</tr>
<tr>
<td>Structured Query DSL</td>
<td>No</td>
</tr>
</tbody>
</table>
V. PERFORMANCE COMPARISON BETWEEN SOLR AND ELASTICSEARCH

One of the issues that Solr and Elasticsearch tools are compared most is their performance figures. Even though these tools are quite similar to one another in terms of being Lucene-based, different figures can be obtained related to their performance. In studies on performance comparisons, it was found out that Solr and Elasticsearch do not greatly have superiority over each other [12][13]. However, sometimes Solr had better performance over Elasticsearch based on intended use, place of use, and changes in some parameters, and vice versa. In this part of this study, some of the performance results conducted so far on Solr and Elasticsearch are listed.

A. Flax.co.uk Tests
Flax.co.uk design, build and support open source powered search applications based in Cambridge U.K. Flax has completed many performance tests on Solr and Elasticsearch. Cluster specifications used in a test are as follows:

- Two machines, each with 96GB RAM
- Two instances of SolrCloud or Elasticsearch on each
- Each instance has 24GB JVM heap
- Four shards
- No replicas

In the first stage of this test, a data consisting of 40 million pieces with 5 to 20 words was created. The results of Solr and Elasticsearch indexes are listed below:

- Elasticsearch indexed them in 30 minutes
- Total index size was 8.8 GB (easily cacheable)
- Solr indexed them in 43 minutes
- Total index size was 7.6 GB

Then, a data consisting of 40 million pieces with 200 to 1000 words was indexed. The results of Solr and Elasticsearch indexes are listed below:

- Elasticsearch indexed them in 179 minutes
- Total index size was 363 GB (not completely cacheable)
- Solr indexed them in 119 minutes
- Total index size was 226 GB

Based on these results, it can be concluded that Elasticsearch performs better with short documents, while Solr had better performance with long documents.

B. Search Test with Indexing
In another study, the first test was designed for conducting a search on servers with similar features (4 nodes, 4 index shards, no replication, 16 GB per node) with 20 million documents. In this process, no extra procedure was followed regarding Solr and Elasticsearch nodes. As seen in Figure 1, it was found out that most of the Elasticsearch queries were completed between 0.10 sec and 0.22 sec as a result of 1000 search inquiries sent to nodes. The same test provided the results of 0.12 sec and 0.54 sec for Solr tool [13].

C. Search Test with Indexing Load
In the second test, servers were requested to operate search inquiries while engaged in indexing process. These tests were also conducted with 20 million entries on servers with similar features. As seen in Figure 2, Elasticsearch had results varying between 0.14 sec and 0.34 sec, Solr completed search inquiry between 0.24 sec and 0.68 sec. Elasticsearch was slightly better than Solr in search tests with indexing load.
D. QPS Test

Queries per second (QPS) is a common measure of the amount of search traffic an information retrieval system, such as a search engine or a database, receives during one second [14].

In QPS test conducted between Elasticsearch and Solr, indexing was continued as a continuation of the previous test. QPS figures were measured for both tools while indexing process was active. As seen in Figure 3, Elasticsearch reached at 30 QPS speed, while Solr was remained at 15 QPS speed when sent similar search requests.

In another QPS test conducted with 40 million pieces of data (between 200 and 1000 words), it was observed that Solr had better performance (Figure 4) [12].

Taking a look at the July 2016 figures published by most-respected DB-Engines web site by database users, Elasticsearch use/liking has increased compared to the previous year, and it moved ahead of Solr (see Table VIII).

Considering the previous studies in literature and the technical data and performance tests of this study, it is seen that Solr and Elasticsearch were better than one another on different tests. These comparison results obtained through this study and the other studies conducted in literature are as follows:

- They are similar tools in terms of technical features.
- Elasticsearch supports more coding language than Solr.
- Solr uses less disk space considering the size of data after indexing.
- Regarding the indexing duration, Elasticsearch had better performance in short data, while Solr was better in long data.
- Both tools are rapid search tools.
- Close performance results were obtained in many different studies.
- Solr and Elasticsearch may have quite different performance characteristics in certain cases [12]
- QPS speed might vary depending on the type of data.
- It is quite hard to predict which one will have higher performance before the tests.
- If a choice shall be made between these two search engines, it is necessary to conduct a test based on the purpose of work.

VI. CONCLUSIONS

Solr and Elasticsearch are two similar search platforms which are both Lucene-based, has similar coding languages, intend use and styles. Solr is one of the search tools that could maintained its popularity even in today’s world.

Elasticsearch, one the other hand, was developed as a way of completing the deficiencies of Solr, and it had a significant place in markets in such a short span of 6 years (2010-2016).
ACKNOWLEDGMENT

We deeply send our regards and thanks to DB-Engines.com, www.solr-vs-elasticsearch.com, and www.Flax.co.uk web sites for the information they shared with us regarding the collection of technical data and performance tests about Solr and Elasticsearch.

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Classification of Heuristic Information by Using Machine Learning Algorithms

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3 Necmettin Erbakan University, Faculty of Engineering, Department of Electrical and Electronics Engineering, Konya, TURKEY, unlersen@yandex.com

Abstract—The User Knowledge Modelling dataset in the UCI machine learning repository was used in this study. The students were classified into 4 class (very low, low, middle, and high) due to the 5 performance data in the dataset. 258 data of 403 data in the dataset were used for training and 145 of them were used for tests. The Weka (Waikato Environment for Knowledge Analysis) software was used for classification. In classification Multilayer Perceptron (MLP), k Nearest Neighbour (kNN), J48, NativeBayes, BayesNet, KStar, RBFNetwork and RBFClassifier machine learning algorithms were used and success rates and error rates were calculated. In this study 8 different data mining algorithm were used and the best classification success rate was obtained by MLP. With Multilayer perceptron neural network model the classification success rates was calculated when there are different number of neurons in the hidden layer of MLP. The best classification success rate was achieved as 97.2414% when there was 8 neurons in the hidden layer. MAE and RMSE values were obtained for this classification success rate as 0.0242 and 0.1094 respectively.

Keywords— Machine learning, Weka, MLP, kNN, J48

I. INTRODUCTION

Data mining is an interdisciplinary subfield of computer science. It is the practice of automatically searching large stores of data to discover patterns and trends that go beyond simple analysis. Data mining uses sophisticated mathematical algorithms to segment the data and evaluate the probability of future events. Data mining is also known as Knowledge Discovery in Data (KDD) [1].

Educational data mining (EDM) is defined as the area of scientific inquiry centered around the development of methods for making discoveries within the unique kinds of data that come from educational settings, and using those methods to better understand students and the settings which they learn in [2]. Many studies in the literature have been proposed to explore the relationship between successes of the students and his/her culture, habits, life style, family structure etc.

Superbý et al. (2006) have search a relation between Academic failures and increase the number of debates among first-year university students. They aims to classify, as early in the academic year as possible, students into three groups: the ‘low-risk’ students, who have a high probability of succeeding, the ‘medium-risk’ students, who may succeed thanks to the measures taken by the university, and the ‘high-risk’ students, who have a high probability of failing (or dropping out). The fact that the most significant variables correlated to academic success have been provided among all the questions asked to 533 first-year university students during the month of November of academic year 2003-04. Finally, it presents the results of the application of discriminant analysis, neural networks, random forests and decision trees aimed at predicting those students’ academic success [3]. Vera et al. (2012) have proposed a genetic programming algorithm and different data mining approaches for solving these problems using real data about 670 high school students from Zacatecas, Mexico. They also propose to use a genetic programming model versus different white box techniques in order to obtain both more comprehensible and accuracy classification rules. They have shown that some approaches such as selecting the best attributes, cost-sensitive classification, and data balancing can also be very useful for improving accuracy [4]. Sen et al. (2012) developed models to predict secondary education placement test results, and using sensitivity analysis on those prediction models using a large and feature rich dataset from Secondary Education Transition System in Turkey. The Support Vector Machines, Artificial Neural Networks and Logistic Regression models have been used for prediction and results were presented [5].

In this study, the User Knowledge Modelling dataset obtained from UCI Machine Learning Repository have been used for classification. In this dataset, there are 5 attributes that used for determining the students’ educational status in 4 class as very low, low, middle, high. For classification 8 machine learning algorithm have been used. The obtained success rates and error values by those algorithms, have been compared.

II. MATERIAL AND METHODS

Software—WEKA

Weka (Waikato Environment for Knowledge Analysis) written in Java, developed at the University of Waikato, New Zealand [6]. Weka supports several standard data mining tasks, more specifically, data pre-processing, clustering, classification, regression, visualization, and feature selection. All techniques of Weka's software are predicated on the
assumption that the data is available as a single flat file or relation, where each data point is described by a fixed number of attributes (normally, numeric or nominal attributes, but some other attribute types are also supported) [7].

**K-Nearest Neighbour Algorithm**

kNN is the supervised learning algorithm, solving the classification problems. Classification is to analyse of features of image, and to belong it to the class which named in advanced. The important thing is determination the features of each category in advance [8]. According to kNN algorithm that was used in classification, characteristics which extracted from classification process, viewing the entire distance among new individual which should be classified and earlier individuals and then the nearest k category is used. As a result of that process test data belongs to the nearest k neighbour category that has more members in certain class. The most important optimization problems in kNN method are identification of neighbour’s number and method of distance calculation algorithm. At the study identification of the optimum k number is done by experiments and Euclidean Distance Calculations method was used as distance calculations method.

Euclidean calculation method [9]:

\[ d(x_i, x_j) = \left( \sum_{x=1}^{n} (x_{ij} + x_{i2})^2 \right)^{1/2} \]

\(x_i\) and \(x_j\) are two different points, and need distance calculation process in between.

**Multilayer Perceptron**

A multilayer perceptron (MLP) is a feed forward artificial neural network model that maps sets of input data onto a set of appropriate outputs. A MLP consists of multiple layers of nodes in a directed graph, with each layer fully connected to the next one. Except for the input nodes, each node is a neuron (or processing element) with a nonlinear activation function. MLP utilizes a supervised learning technique called back propagation for training the network. MLP is a modification of the standard linear perceptron and can distinguish data that are not linearly separable [6].

**RBF Network**

It is an artificial neural network that uses radial basis functions as activation functions. The output of the network is a linear combination of radial basis functions of the inputs and neuron parameters. Radial basis function networks have many uses, including function approximation, time series prediction, classification, and system control [6].

**BayesNet**

It is probabilistic graphical model (a type of statistical model) that represents a set of random variables and their conditional dependencies via a directed acyclic graph (DAG). For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases [6].

**Naive Bayes**

Naive Bayes classifiers are highly scalable, requiring a number of parameters linear in the number of variables (features/predictors) in a learning problem. Maximum-likelihood training can be done by evaluating a closed-form expression which takes linear time, rather than by expensive iterative approximation as used for many other types of classifiers [6].

**J48**

J48 algorithm of Weka software is a popular machine learning algorithm based upon J.R. Quilan C4.5 algorithm. All data to be examined will be of the categorical type and therefore continuous data will not be examined at this stage. The algorithm will however leave room for adaption to include this capability [6, 7].

**KStar**

K-star or K* is an instance-based classifier. The class of a test instance is based on the training instances similar to it, as determined by some similarity function. It differs from other instance-based learners in that it uses an entropy-based distance function. [10].

### III. RESULTS AND DISCUSSION

403 sample data at User Knowledge Modelling dataset were processed by using Weka program. The classification success rates at different neurons numbers in the hidden layers and MAE, RMSE error rates were determined. The diagram demonstrating the changes in MAE and RMSE error values based on the number of neighbours in the hidden layer is demonstrated in Figure 1.

**TABLE I**

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>THE SUCCESS RATE AND ERROR VALUES OBTAINED BY USING MLP CLASSIFIER</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of neurons in hidden layer</td>
<td>Error Rate</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 1** Variation of error rate based on the number of neurons in hidden layer

The classification success of the state of eye same was obtained by using kNN algorithm with the same dataset. Classification success for different k neighbour values with kNN algorithm in the state of the eye to be open or closed were
different machine learning algorithms can be seen in Table 3. The success and error rates obtained using 8 different machine learning algorithms (Multilayer Perceptron, kNN, J48, NaiveBayes, BayesNet, RBFNetwork, RBFClassifier, BayesNet and Kstar) can be seen in Table I. The diagram demonstrating the error values obtained based on different machine learning algorithms can be seen in Figure 2.

Table II: Success Rate Obtained by Using Various Machine Learning Algorithms

<table>
<thead>
<tr>
<th>Machine Learning Algorithms</th>
<th>Classification Success (%)</th>
<th>MAE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>MLP</td>
<td>97.2414</td>
<td>0.0242</td>
<td>0.1094</td>
</tr>
<tr>
<td>kNN</td>
<td>87.5862</td>
<td>0.1037</td>
<td>0.2324</td>
</tr>
<tr>
<td>J48</td>
<td>91.0345</td>
<td>0.0481</td>
<td>0.2092</td>
</tr>
<tr>
<td>NaiveBayes</td>
<td>84.8276</td>
<td>0.1173</td>
<td>0.2582</td>
</tr>
<tr>
<td>RBFNetwork</td>
<td>93.7931</td>
<td>0.0411</td>
<td>0.1567</td>
</tr>
<tr>
<td>RBFClassifier</td>
<td>71.0345</td>
<td>0.2143</td>
<td>0.2988</td>
</tr>
<tr>
<td>BayesNet</td>
<td>86.8966</td>
<td>0.1312</td>
<td>0.2485</td>
</tr>
<tr>
<td>Kstar</td>
<td>81.3793</td>
<td>0.1122</td>
<td>0.2695</td>
</tr>
</tbody>
</table>

In this study, students have been classified about their success in the school as very low, low, middle and high by using their daily habits. By this intention, popular data mining algorithms like kNN, MLP, J48, NaiveBayes, RBFNetwork, RBFClassifier, BayesNet and Kstar, have been used and compared with each other. At obtained classification success rates, success rates made with kNN algorithm is seen to be higher. At classification success rates obtained with kNN algorithm, highest classification success was obtained for 3 neighbour values and this value is 87.5862%. At this neighbour value, MAE error value is 0.1037 and RMSE error value is 0.2324. It is seen that classification success rates obtained by using Multilayer perceptron model is too low for kNN classifier. While the number of neurons in the hidden layer is 8, highest classification success was obtained and this value is 97.2414%. At this neurons number in the hidden layer, MAE error value is 0.0242 and RMSE error value is 0.1094.

The success rates obtained using J48, NaiveBayes, RBFNetwork, RBFClassifier, BayesNet and Kstar classification algorithms were found as 91.0345%, 84.8276%, 93.7931%, 71.0345%, 86.8966% and 81.37935 respectively.

Fig. 3 Variation of error rate based on the machine learning algorithms

REFERENCES

Estimation of Credit Card Customers Payment Status by Using kNN and MLP

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Abstract—The Default of Credit Card Clients dataset in the UCI machine learning repository was used in this study. The credit card customers were classified if they would do payment or not (yes=1 no=0) for next month by using 23 information about them. Totally 30000 data in the dataset’s 66% was used for training and rest of them as 33% was used for tests. The Weka (Waikato Environment for Knowledge Analysis) software was used for estimation. In estimation Multilayer Perceptron (MLP) and k Nearest Neighbour (kNN) machine learning algorithms was used and success rates and error rates were calculated. With kNN estimation success rates for various number of neighbourhood value was calculated one by one. The highest success rate was achieved as 80.6569% when the number of neighbour is 10. With MLP neural network model the estimation success rates was calculated when there are different number of neurons in the hidden layer of MLP. The best estimation success rate was achieved as 81.049% when there was only one neuron in the hidden layer. MAE and RMSE values were obtained for this estimation success rate as 0.3237 and 0.388 respectively.

Keywords—Data mining, Weka, MLP, kNN

I. INTRODUCTION

Credit card is a payment card issued to users (cardholders) as a method of payment. It allows the cardholder to pay for goods and services based on the holder's promise to pay for them [1]. The issuer of the card (usually a bank) creates a revolving account and grants a line of credit to the cardholder, from which the cardholder can borrow money for payment to a merchant or as a cash advance. For the banks the most important thing during credit card marketing is the payment capability of customers. In this study a payment status estimation have been proposed for credit card customers. For this purpose data mining algorithms have been used.

Data mining is a computational process that reveals patterns in data sets by using such methods like artificial intelligence, machine learning, statistics etc [2]. The methods used in data mining are investigated in two groups as predictive and descriptive. In predictive methods, a model is created by using a dataset whose results are known. For example in a bank, the properties of customers who pay their credits back can be revealed and a model can be created by using previous data sets about funding of them. Afterward this model can be used on new customers for determining the possibility of pay their credits back. In descriptive methods, a relationship can be searched between two data sets. For example, the shopping habits of two different culture may be investigated for similarity [3].

Data mining methods can be divided into three groups due to their function.
1. Classification and Regression
2. Clustering
3. Association Rules

Data mining methods are used to classifying the data set. In classification, training examples are used to learn a model that can classify the data samples into known classes. The classification process involves following these steps: creating a training data set, identifying class attributes and classes, identifying useful attributes for classification, relevance analysis, learning a model using training examples in the training set and using the model to classify the unknown data [4].

In this study, an estimation about whether the payment for next month is going to be done or not by the credit card clients in the default credit card clients data set with 23 attributes obtained from the UCI Machine Learning Repository, have been done. For estimation kNN and MLP algorithms have been used. The success rates and error values have been presented and compared with each other.

II. MATERIAL AND METHODS

Dataset

In this study the default of credit card clients data set obtained from UCI Machine Learning Repository have been used. This data set have been obtained from Credit cart customers’ default payments in Taiwan. In this data set there are 23 attributes and a binary type class. These attributes and descriptions are as follow [5].

X1: Amount of the given credit (NT dollar): it includes both the individual consumer credit and his/her family (supplementary) credit.
X2: Gender (1 = male; 2 = female).
X3: Education (1 = graduate school; 2 = university; 3 = high school; 4 = others).
X4: Marital status (1 = married; 2 = single; 3 = others).
X5: Age (year).
X6 - X11: History of past payment from April to September, 2005. The measurement scale for the repayment status is: -1 = pay duly or number of the delayed month.
X12-X17: Amount of bill statement (NT dollar).
X18-X23: Amount of previous payment (NT dollar).
X24: Class (0 = No; 1 = Yes)

Software-WEKA

Developed by Waikato University in New Zealand, WEKA is an open-source data mining software with a functional graphical interface which incorporates machine learning algorithms [6]. WEKA includes various data pre-processing, classification, regression, clustering, association rules, and visualization tools. The algorithms can be applied on the data cluster either directly or by calling via Java code [7][8]. They are also suitable for developing new machine learning algorithms.

Machine learning algorithms

K-Nearest Neighbor Algorithm: The k-NN is a supervised learning algorithm that solves classification problems. Classification is the examination of the attributes of an image and the designation of this image to a predefined class. The important point is the determination of the features of each category in advance [9]. According to the kNN algorithm used in the classification, based on the attributes drawn from the classification stage, the distance of the new individual that is wanted to be classified to all previous individuals is considered and the nearest k class is used. As a result of this process, test data belongs to the k-nearest neighbour category that has more members in a certain class. The most important optimization problems in the kNN method are the identification of the number of neighbours and the method of distance calculation algorithm. In the study, the identification of the optimum k number is performed with experiments, and the Euclidean Distance Calculations method is used as a distance calculation method.

Euclidean calculation method [10]:
\[ d(x_i, x_j) = \left( \sum_{p=1}^{P} (x_{ip} + x_{jp})^2 \right)^{\frac{1}{2}} \]

xi and xj are two different points, and we need distance calculation process in between.

Multilayer Perceptron: It is a feed forward type artificial neural network model which maps input sets onto appropriate output sets. A MLP is composed of multiple layers of nodes where each layer is connected to the next. Each node is a processing element or a neuron that has a nonlinear activation function except the input nodes. It uses a supervised learning technique named back propagation and it is used for training the network. The alteration of the standard linear perceptron, MLP is capable of distinguishing data which are not linearly separable [8].

III. RESULTS AND DISCUSSION

In the study, WEKA software was used in order to estimate the payment for next month is going to be done or not by the credit card. Using the kNN algorithm, the estimation success rates of payment were obtained for different k-neighbour values. Also, root mean square error (RMSE) and mean absolute error (MAE) values were obtained. The estimation success rates obtained with kNN algorithm, and MAE and RMSE values can be seen in Table 1. The diagram demonstrating the changes in MAE and RMSE error values based on the number of neighbours in the estimation performed with the kNN algorithm is shown in Figure 1.

<table>
<thead>
<tr>
<th>Neighborliness Number (k)</th>
<th>Estimation Success (%)</th>
<th>MAE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>73.3039</td>
<td>0.2673</td>
<td>0.5168</td>
</tr>
<tr>
<td>2</td>
<td>78.4608</td>
<td>0.2727</td>
<td>0.4525</td>
</tr>
<tr>
<td>3</td>
<td>77.1176</td>
<td>0.274</td>
<td>0.4285</td>
</tr>
<tr>
<td>4</td>
<td>79.3824</td>
<td>0.2731</td>
<td>0.4132</td>
</tr>
<tr>
<td>5</td>
<td>78.8627</td>
<td>0.2727</td>
<td>0.4049</td>
</tr>
<tr>
<td>6</td>
<td>80.049</td>
<td>0.2733</td>
<td>0.4002</td>
</tr>
<tr>
<td>7</td>
<td>79.8725</td>
<td>0.2735</td>
<td>0.3961</td>
</tr>
<tr>
<td>8</td>
<td>80.3137</td>
<td>0.2742</td>
<td>0.394</td>
</tr>
<tr>
<td>9</td>
<td>80.2843</td>
<td>0.2742</td>
<td>0.3913</td>
</tr>
<tr>
<td>10</td>
<td>80.6569</td>
<td>0.2743</td>
<td>0.3897</td>
</tr>
</tbody>
</table>

Fig. 1 Variation of error rate based on the number of neighbourhood

The data in the same dataset were processed using the MLP model, and the estimation success rates of credit card payments. The estimation success rates of different number of neurons in the hidden layer, and MAE and RMSE error values were obtained. In the MLP model, the training was performed by
taking the learning rate value as 0.3, momentum value as 0.2 and iteration number as 500. The estimation success rates, and MAE and RMSE values obtained using the MLP model can be seen in Table 2. The diagram demonstrating the changes in MAE and RMSE error values based on the number of neighbours in the hidden layer is demonstrated in Figure 2.

IV. CONCLUSION
In this study, credit card clients’ behaviours about payment have been estimated. For this purpose machine learning algorithms like kNN and MLP have been used. The estimation success rates and error values of kNN and MLP were calculated. It was observed that the success rate was higher for the estimation performed by using the MLP algorithm. The highest estimation success rate was achieved when the number of neurons in the hidden layer was 1 and the success rate was 81.049%. The MAE error value was 0.3237 and the RMSE error value was 0.388 when there is only one neuron in the hidden layer. For the estimation success rates obtained using K-Nearest Neighbour Algorithm, the highest estimation success rate was achieved for 10 neighbourhood values, and it was 80.6569%. For this neighbourhood value, the MAE error value was 0.2743 and the RMSE error value was 0.3897.

REFERENCE


**Blind Audio Source Separation Using Independent Component Analysis and Independent Vector Analysis**

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**Abstract**—Blind Source Separation (BSS) is one of the most important and challenging problem for the researchers in audio and speech processing area. In the literature, many different methods have been proposed to solve BSS problem. In this study, we have compared the performance of three popular BSS methods based on Independent Component Analysis (ICA) and Independent Vector Analysis Models, which are Fast-ICA, Kernel-ICA and Fast-IVA. We collected experimental data by recording speech from 13 people. Three different scenarios are proposed to compare the performance of BSS methods effectively. Experimental results show that the Fast-IVA has better performance than the ICA based methods according to performance metrics of Source-to-Artifact Ratio, Source-to-Distortion Ratio and Source-to-Noise Ratio. But ICA methods give better results than Fast-IVA according to the Source-to-Interference Ratio.

**Keywords**—Blind source separation, Independent component analysis, Independent vector analysis

**I. INTRODUCTION**

Blind Source Separation (BSS) is one of the most important problems in speech processing area. The better description of this problem can be represented by this question: How can we accurately determine what a particular person talks among several speakers at the same time? Figure 1 shows an illustration of BSS problem. This problem describes the situation of focusing on one speaker in case of several persons talking simultaneously in same room. To separate the mixed speech signals to obtain just a speech signal which belongs to a particular speaker is very challenging and complicated problem [1]. In the literature, many different methods based on signal processing and statistics were proposed to solve BSS problem.

**Fig. 1. BSS Problem**

BSS was firstly addressed by Herault and Jutten in 1985 [2]. In their work, the sound is directly transmitted to the microphones without any delay which known as standard blind source separation. Then Bell and Sejnowski in 1995 developed the Independent Component Analysis (ICA) method to solve BSS problem when the sources are mixed simultaneously [3]. Also some different algorithms based on ICA such as Fast-Fixed Point ICA [4], the Jade-ICA [5], the EGLD-ICA, the MS-ICA [6], and the Kernel-ICA [7] were proposed in literature.

As a result, BSS problem becomes more complicated for real room environment and this speech propagation problem is called convolutive blind source separation (CBSS) [8].

In the literature, some solutions were proposed in the time domain. Due to the complicated calculation caused by convolution, Parra et al [15] suggested another method based on frequency domain. In frequency domain, the convolution is replaced with multiplication to have low cost in terms of execution time. However, the frequency based methods still have scaling and permutation ambiguities. To prevent permutation problem, an advanced method named Independent Vector Analysis (IVA) was proposed by Kim et al [9].

In this study we have compared the performance of two ICA based algorithms and Fast-IVA according to performance measurement metrics commonly used for BSS problem. This paper is organized as follow: Section II contains the standard ICA method and its properties, ICA based algorithms (Fast-ICA and Kernel-ICA). Section III explains details of Fast Fixed Point IVA algorithm. Section IV gives brief information about the commonly used performance measurement metrics. Experimental results obtained by using different proposed scenarios are represented in Section V. Finally the conclusion is presented in the last section.

**II. INDEPENDENT COMPONENT ANALYSIS**

Independent Component Analysis (ICA) is one of the most popular BSS methods. ICA was used extensively for many applications in various field of science and engineering. ICA, which is a statistical computational method, was employed to find underlying hidden factors among set of random vectors. The main aim of ICA method is to obtain the independent components (ICs), which are linearly independent or as independent as possible, by finding a linear representation of non-Gaussian data.
A. ICA MODEL

Suppose that we have two persons talking simultaneously in a room and two microphones were replaced in different places for recording their talking. In this way, two speech signals are recorded by these microphones. These signals can be represented as \( x_1(t) \) and \( x_2(t) \) where \( t \) is the time index. The signals from the speakers can also be represented as \( s_1(t) \), \( s_2(t) \), so the linear combination of the speech signals can be expressed as:

\[
\begin{align*}
  x_1(t) &= a_{11}s_1(t) + a_{12}s_2(t) \\
  x_2(t) &= a_{21}s_1(t) + a_{22}s_2(t)
\end{align*}
\]  

Where \( s_1 \) and \( s_2 \) are the original speech signals, \( a_{11}, a_{12}, a_{21} \) and \( a_{22} \) denote the parameters that depend on the distance between the speakers and the microphones. Assume that \( M \) is the number of observed mixture signals and \( L \) is the number of independent source signals. Then the model will be as follow:

\[
x_i = \sum_{j=1}^{L} a_{ij}s_j, i = 1 \ldots M
\]

Since instead of summations like in (2), using vector-matrix notation is more suitable to, the ICA model can be rewritten as:

\[
x = As \quad (3)
\]

where \( A \) is an unknown matrix called the mixing matrix, \( x \) is a vector of the observed signals and \( s \) is a vector of the source signals. The challenge in the ICA method is the estimation of both \( A \) and \( s \) by using only the observed random vector \( x \). It is assumed that the unknown mixing matrix should be invertible or pseudo-invertible. After the matrix \( A \) estimation, its inverse denoted by \( W \) can be computed. As a result ICs denoted by \( y \) is obtained simply by using following equation.

\[
y = Wx \quad (4)
\]

ICA requires some assumptions related to the sources and the mixing process. These assumptions make this method different from the other source separation approaches [10]. The first assumption is that the sources being considered are statistically independent. The other one is that the sources must have non-Gaussian distribution. The last one is to have invertible mixing matrix [10].

Two inherent ambiguities are hold in ICA framework. One of them is magnitude and scaling ambiguity, and the other is the permutation ambiguity [10].

Some preprocessing steps can be performed to improve the performance of ICA based methods. Some useful preprocessing techniques are Centering and Whitening[10].

There are several kinds of algorithm based on ICA. In this study we have performed two of them, which are widely used.

B. FAST FIXED-POINT ICA

The Fast Fixed-Point ICA (Fast-ICA) algorithm based on mutual information utilizes higher order statistics for the retrieval of independent sources [4]. Fast ICA has two estimation approaches:

(i) deflation approach to estimate ICs one by one and (ii) symmetric approach to estimate ICs simultaneously[4].

Fast-ICA uses fixed-point algorithm of ICA as follow:

\[\text{Algorithm} \quad \text{Fast fixed-point ICA [4]}\]

1. Take a random initial vector \( w(0) \) of norm 1, Consider \( k = 1 \).
2. Let \( w(k) = \text{Ex}(w(k-1)T \cdot x)^3 w(k-1) \). Estimate the expectation using a large sample of \( x \) vectors.
3. Divide \( w(k) \) by its norm.
4. if \( |(w(k)T w(k-1)| \) is not close enough to 1, consider \( k = k + 1 \) and go back to step 2, otherwise return the vector \( w(k) \) as output.

C. KERNEL INDEPENDENT COMPONENT ANALYSIS

The Kernel Independent Component Analysis (Kernel-ICA) is a different version of ICA model that based on the minimization of a contrast function based on kernel ideas. Kernel-ICA rely on an entire function space of candidate nonlinearities. In particular, Kernel-ICA works with the functions in a reproducing kernel Hilbert space using canonical correlation based functions. The Kernel trick is used to make the search over this space efficiently. Some new modifications were proposed to make the algorithm more robust and efficient to different source distributions [7]. In short, Kernel-ICA use optimization methods for canonical correlations to reproduce kernel Hilbert space.

III. INDEPENDENT VECTOR ANALYSIS

Independent Vector Analysis (IVA), which is one of the most advanced method, show better performance in the field of BSS. Theoretically this method overcomes the permutation problem that inherent from ICA. It is designed to remove the dependency between different source vectors while keeping the dependency within individual source vectors. The problem is transformed into frequency domain to reduce computational complexity of the time domain. The noise free model in the frequency domain can be defined as follow:

\[
X(k) = H(k)s(k) \quad (5)
\]

\[
\hat{S}(k) = W(k)x(k) \quad (6)
\]

Where the index \( k = 1, 2, \ldots, K \) indicate the k-th frequency bin, and \( K \) is the number of frequency bins, \( x(k) = [x_1(k), x_2(k), x_m(k)]^T \) represent the observed signal vector in the frequency domain, \( s(k) = [s_1(k), s_2(k), s_m(k)]^T \) denotes the original source vector in the frequency domain and \( \hat{s}(k) = [\hat{s}_1(k), \hat{s}_2(k), \hat{s}_m(k)]^T \) represents the estimated source vector in the frequency domain. And \( (.)^T \) is the vector transpose. The number of microphones and the number of sources are represented by \( m \) and \( n \), respectively. \( H(k) \), which is a \( mn \) dimension matrix, denotes the mixing matrix and \( W(k) \), which is a \( nm \) dimension matrix, denotes the unmixing matrix.

In this study, we assume that the number of sources and the number of microphones should be the same. The main goal is that the sources should be estimated by using only the observed (mixed) signals.

An objective function is defined to separate multivariate sources from multivariate observations. Kullback-Leibler di-
vergence between two functions as the measure of dependence is employed in IVA. These two functions are the joint probability density function \( p = 1, \ldots, n \) and the product of probability density functions of the individual source vectors \( \Pi q(\hat{s}_i) \). This function can be defined as follow:

\[
J = kL(p(\hat{s}_1, \ldots, \hat{s}_n) || \Pi q(\hat{s}_i)) = \text{const} - \sum_{k=1}^{K} \log|\det(W)| - \sum_{k=1}^{n} E[\log q(\hat{s}_i)]
\]

We can keep the dependency between the components of each vector, and remove the dependency between the source vectors if the cost function is minimized [11].

In literature, there are different version of IVA such as NG-IVA, Fast-IVA and Aux-IVA [11]. In this study Fast-IVA algorithm is employed for BSS.

A. FAST FIXED-POINT INDEPENDENT VECTOR ANALYSIS

This algorithm utilizes Newtons method to update the original IVA method, which converges quadratically and select an efficient learning rate. In order to apply Newtons method in the update rules, polynomial approximation of a quadratic Taylor series is produced in the notations of complex variables. In this way, it can be used for a contrast function of complex-valued variables [11]. The contrast function used by Fast IVA is as follows:

\[
J = \sum_{k=1}^{n} E[G(\sum_{k=1}^{K} |\hat{S}_i(k)|^2) \sum_{k=1}^{K} \lambda_i^{(k)} (w_i(k)w_i(k) - 1)]
\]

where, \( \lambda_i \) is the ith Lagrange multiplier, and \( w_i(k) \) denotes the ith row of the unmixing matrix \( W \), \( G() \) is the non-linearity function, which can take on several different forms as discussed in [11]. The learning rule can be defined as follow with normalization:

\[
(W_i^{(k)})^H \leftarrow E[G(\sum_{k=1}^{K} |\hat{S}_i(k)|^2) + \sum_{k=1}^{K} |S_i(k)|^2 G''(\sum_{k=1}^{K} |S_i(k)|^2)] x(W_i^{(k)})^H - E[\hat{S}_i(k)^* G'(\sum_{k=1}^{K} |S_i(k)|^2)^x K]
\]

where \( G'(\cdot) \) and \( G''(\cdot) \) represent the first and second derivative of \( G(\cdot) \), respectively. And if we use that for all sources, we can construct an unmixing matrix \( W(k) \) to be decorrelated with

\[
W(K) \leftarrow (W(K)(W(K))^T)^{-1/2} W(K)
\]

IV. PERFORMANCE MEASUREMENT

There are several performance measurement metrics to evaluate the quality of estimated signals obtained by BSS methods. The performance of BSS algorithms can be measured by comparing each estimated source \( j \) to a given true source \( j \). The measuring processing includes two successive steps [12].

The first step involves decompose \( j \) as:

\[
\hat{s}_j = s_{\text{target}} + e_{\text{interf}} + e_{\text{noise}} + e_{\text{artif}}
\]

Where \( s_{\text{target}} = f(s_j) \) denotes the version of \( s_j \) modified by an allowed distortion, and the interferences, noise, and artifacts error terms are represented by where, \( s_{\text{interf}}, s_{\text{noise}} \) and \( s_{\text{artif}} \), respectively.

The second step involves computing the energy ratios in order to estimate the relative amount of each of these four terms either on the local frames of the signal or the whole signal duration. The way of decomposing into four terms are given in [12] in detail. Relevant energy ratios between these terms are defined.

After the decomposition of \( j \) following the procedures given in [21]. Numerical performance criteria was defined by computing energy ratios expressed in decibels. Definition of source-to-distortion ratio (SDR), the source-to-interference ratio (SIR), source-to-artifact ratio(SAR) and source-to-noise ratio(SNR) are given below, respectively

\[
SDR := 10 \log_{10} \frac{||s_{\text{target}}||^2}{||e_{\text{interf}} + e_{\text{noise}} + e_{\text{artif}}||^2}
\]

\[
SIR := 10 \log_{10} \frac{||s_{\text{target}}||^2}{||e_{\text{interf}}||^2}
\]

\[
SAR := 10 \log_{10} \frac{||s_{\text{target}} + e_{\text{interf}}||^2}{||e_{\text{artif}}||^2}
\]

\[
SNR := 10 \log_{10} \frac{||s_{\text{target}} + e_{\text{interf}}||^2}{||e_{\text{noise}}||^2}
\]

V. EXPERIMENTAL RESULTS

The performance of Fast-ICA, Kernel-ICA and Fast-IVA methods for separating mixing speech signals was compared. We collected 13 speech signals recorded in real room, each record long 10sec in Arabic language with 16 kHz. These records are mixed by using random parameters.

In our experiment, three different scenarios are proposed to compare performance more effectively. The first scenario includes measuring and comparing the performance of Fast-ICA, Kernel-ICA and Fast-IVA for separating mixing speech signals without noise, as shown in Figure 2. Figure 3 illustrates the second scenario which shows the performance of these methods for separating mixed speech signals with Gaussian noise added to signals before mixing. In the third scenario, we add Gaussian noise to the signals after mixing as shown in Figure 4. Since Gaussian noise is added to the sources or mixtures in the second and third scenarios, Savitzky-Golay smoothing filter [13] is performed to enhance the signals before the separation.

![Fig. 2. Illustration of Scenario 1 for the experiment](image)

![Fig. 3. Illustration of Scenario 2 for the experiment](image)
In each scenario, we have created 77 different mixture signals from 13 original sources using different mixture parameters. The Fast-IVA use the Short time Fourier Transform of length 1024, and the sampling frequencies were 16 kHz. The results of our experiment for each scenario show that: the Fast-IVA has better performance comparing with Fast-ICA and Kernel-ICA according to SAR, SDR and SNR performance metrics. But we notice that Fast-ICA and Kernel-ICA methods have better performance than Fast-IVA according SIR as shown in Table 1, Table 2 and Table 3.

In this study, We have implemented Fast-ICA algorithm in MATLAB. A different version of Fast-ICA algorithm can be downloaded from http://research.ics.aalto.fi/ica/fastica/code/dlcode.shtml. For the other BSS methods (Kernel-ICA and Fast-IVA), we have used the shared codes. The kernel-ICA package is Copyright (c) 2002 by Francis Bach [14], and Fast-IVA can be implemented and compared using different scenarios.

VI. THE CONCLUSION

Blind source separation (BSS) is one of the most important and challenging problem for the researchers in audio and speech processing fields. In this study, we have implemented and compared three popular BSS methods, which are Fast-ICA, Kernel-ICA and Fast-IVA. Three different scenarios were proposed to measure the performance of BSS methods extensively using four different commonly used performance metrics. According to experimental results Fast-IVA shows better performance than the other methods according to SDR, SAR and SNR metrics. But Fast-ICA and Kernel-ICA methods have high performance than Fast-IVA according to SIR metric. In future, some advanced BSS algorithms will be implemented and compared using different scenarios.

REFERENCES

[15] L Parra, C Spence, Convolutive blind separation of non-stationary sources, IEEE Trans. Speech Audio Process. 8, 32064 (R2013a). The algorithms are also compared in terms of execution time. The time that needed for running the algorithms was also given in Table 4.

TABLE I

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Criteria</th>
<th>SAR</th>
<th>SDR</th>
<th>SIR</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD</td>
<td>1.084</td>
<td>1.087</td>
<td>2.574</td>
<td>5.0966</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.0899</td>
<td>1.0992</td>
<td>2.03176</td>
<td>3.14367</td>
</tr>
<tr>
<td>Fast-IVA</td>
<td>Average</td>
<td>7.6494</td>
<td>8.278</td>
<td>9.4262</td>
<td>8.7521</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.0904</td>
<td>1.087</td>
<td>1.7975</td>
<td>6.1130</td>
</tr>
</tbody>
</table>

TABLE II

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Criteria</th>
<th>SAR</th>
<th>SDR</th>
<th>SIR</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast-ICA</td>
<td>Average</td>
<td>5.0701</td>
<td>5.0289</td>
<td>27.705</td>
<td>-13.660</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.8008</td>
<td>1.7975</td>
<td>3.0743</td>
<td>2.8805</td>
</tr>
<tr>
<td>Kernel-ICA</td>
<td>Average</td>
<td>4.9694</td>
<td>4.9435</td>
<td>28.9186</td>
<td>-14.035</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.8174</td>
<td>1.8799</td>
<td>2.61869</td>
<td>2.6280</td>
</tr>
<tr>
<td>Fast-IVA</td>
<td>Average</td>
<td>8.8166</td>
<td>6.3595</td>
<td>15.0365</td>
<td>2.0093</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>3.1440</td>
<td>3.4346</td>
<td>9.9977</td>
<td>1.3985</td>
</tr>
</tbody>
</table>

TABLE IV

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Running time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast-ICA</td>
<td>24.778 s</td>
</tr>
<tr>
<td>Fast-IVA</td>
<td>30.006 s</td>
</tr>
<tr>
<td>Kernel-ICA</td>
<td>160.567 s</td>
</tr>
</tbody>
</table>

TABLE III

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Criteria</th>
<th>SAR</th>
<th>SDR</th>
<th>SIR</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast-ICA</td>
<td>Average</td>
<td>5.0037</td>
<td>4.9645</td>
<td>27.8722</td>
<td>-13.745</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.8200</td>
<td>1.8186</td>
<td>5.1256</td>
<td>2.7637</td>
</tr>
<tr>
<td>Kernel-ICA</td>
<td>Average</td>
<td>4.9694</td>
<td>4.9435</td>
<td>28.9186</td>
<td>-14.035</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.8174</td>
<td>1.8199</td>
<td>2.61689</td>
<td>2.6280</td>
</tr>
<tr>
<td>Fast-IVA</td>
<td>Average</td>
<td>8.8166</td>
<td>6.3595</td>
<td>15.0365</td>
<td>2.0093</td>
</tr>
<tr>
<td></td>
<td>SD</td>
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<td>3.4346</td>
<td>9.9977</td>
<td>1.3985</td>
</tr>
</tbody>
</table>
Note Recognition from Monophonic Musical Signals
By Using Neural Network

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Abstract— In this work, note recognition from monophonic musical signals is studied. It is aimed to achieve a musical note from the fundamental frequency. Artificial Neural Networks (ANN) is used in order to estimate the fundamental frequency. Firstly, around 6-10 seconds audio recordings for each musical notes are taken with the flute. Certain number of frames are taken from these audio recordings and used for training of the ANN. After training, any parts that are played on the flute are tested. The musical notes was found correctly on the tested parts that are played on the flute.

Keywords — Artificial neural networks (ANN), Signal processing, Monophonic music signals.

I. INTRODUCTION

Music note recognition is one of the most important part of some music applications. This fact is emphasized on [1] and in more specific works such as music transcription [2,3], song retrieval [4,5] and others [6,7,8].

ANN is one the useful techniques to overcome the drawbacks of classical signal processing and filtering techniques. It is claimed [3] that no work that refers to ANN for music note recognition has ever existed prior to their work [1].

Monophonic means the production of musical signal from single source in a time interval. Sound produced by a variety of sources in different time intervals does not disrupt the monophony. Sound received in the same structure from the group consisting of multiples wires can be considered as monophonic at the stringed instrument. But as in the Turkish instrument “baglama”, produced sound by a thick (bam) wire and one or two thin wires cannot be regarded as monophonic. In the polyphony, multiple voices are produced in the same time range [9].

Based on the physiological relationship all the sounds in music can be handled four variables in a very simple way [10]:
1. Repetition rate of the audio signal is related to the fundamental frequency.
2. The amplitude of the audio signal associated with rotundity
3. The shape of the audio signal associated with the timbre of musical instruments
4. According to the sensors location of the sound source are associated with the position of the sensors different detection.

The last parameter is not taken into account in the existing systems. But making recordings with people's ideas will give healthier and more productive results. These peoples are musical instruments producers, users, recorders and listeners.

The frequency content of a note is made up of a fundamental frequency and its exact multiples. As in Figure 1; if fundamental frequency is f0 then first harmonic is 2f0 second harmonic is 3f0 and so on [9].

Because of overlapping of fundamental frequency and harmonic content, sound produced by a group of artists or instruments is percepted as same note.

Fig. 1 Frequency content of monophonic musical signals [11]

The fundamental frequency relationship of two consecutive notes f0 and f1 is given in Equation 1.

\[ k = \frac{f_0}{f_1} = 2^{1/12} \approx 1.05946 \] (1)

A4 (440 Hz) is accepted La note other fundamental frequency values is calculated according to the Equation 1. This means that each octave is divided into 12 equal intervals [9].

II. MATERIAL AND METHOD

In this work, due to the simplicity of the harmonic structure recordings from the musical instrument called “block flute” is studied. Recordings are obtained by Sound Recorder in Windows Operating System, in 21.05 kHz sampling frequency and .wav format.

Flut is a musical tool designed to produce sound in equal order. Samples notes (do, re, mi, fa, sol, la, si, do) are taken of
the notes that are played on the flute. For each note 6-10 second audio file is saved. The audio recording of file belongs to do note, and its zooming part around 200 samples are shown in Figure 2. Periodic structure in the zoomed image can be seen very clearly. Frames containing 200 samples are obtained from these recordings performed separately for each note. Values are normalized to the range -1 to 1 and placed on a column of the data matrix. This procedure is repeated 400 times for each note. As a result, 200x400 sized matrix is created for a note. For 8 notes, by concatenating these 8 matrices, finally 200x3200 sized data matrix is formed.

A. Artificial neural networks (ANN)

One efficient way of solving complex problems is following the lemma “divide and conquer”. A complex system may be decomposed into simpler elements, in order to be able to understand it. Also simple elements may be gathered to produce a complex system [12]. Networks are one approach for achieving this. There are a large number of different types of networks, but they all are characterized by the following components: a set of nodes, and connections between nodes. One type of network sees the nodes as ‘artificial neurons’. These are called artificial neural networks (ANN). An artificial neuron is a computational model inspired in the natural neurons [13]. In other Words, Artificial neural networks are an attempt at modeling the information processing capabilities of nervous systems [14]. As shown in Figure 4, Biological Natural neurons receive signals through synapses located on the dendrites or membrane of the neuron. When the signals received are strong enough, the neuron is activated and emits a signal though the axon. This signal might be sent to another synapse, and might activate other neurons [13].

Figure 5 shows the structure of an artificial neural neuron with \( X_1, X_2, X_3, \ldots, X_n \) inputs. Each input channel i can transmit a real value \( x_i \). The input channels have an associated weight, which means that the incoming information \( x_i \) is multiplied by the corresponding weight \( W_{1j}, W_{2j}, W_{3j}, \ldots, W_{nj} \).

The sum function \( \text{net}_j \) computed according to the Equation 2.
The output of the processing element is calculated by netj value passed through the activation function (Equation 3).

\[ \theta_j = f(\text{net}_j) = f\left(\sum_{i=1}^{n} x_i * w_{ij}\right) \] (3)

The task of neural cells briefly is that controlled in response to the output value of the input value Xn. Until obtaining the desired output value is updated weight Wnj. Learning neural network takes place with updating Wnj weight.

III. EXPERIMENTAL STUDIES

This work describes the design of the ANN is performed with software MATLAB R2015a. 200 neurons in the input layer, 40 neurons in the output layer and 8 neurons in the hidden layer is used for Multi-layer ANN. traincgf (Scaled conjugate gradient backpropagation) is used as a training algorithm. The neuron that has highest value is selected from 8 neuron at the output of ANN. Each note (do, re, mi, fa, sol, la, si, do) is represented by numbers from 1 to 8 which are the the highest value of the output of the ANN.

Designed and trained ANN is tested with consecutive played notes by the flute. When notes are played at low frequencies to high frequencies, it is expected as a result of stairs as shown Figure 5. Figure 6 illustrates of achieving the expectations. Consecutive played do, re, mi, fa, sol, la, si and do notes are overlapped with the corresponding numbers.

![Fig. 5 Consecutive sort of musical notes](image)

Trained ANN was tested *Twinkle Twinkle Little Star* song for a second test. This song is an international song. The melody of the song and even music are taught in basic education institutions by many people. The song notes are given in Figure 9. Figure 10 shows very clearly that the values are assigned to the notes correctly. The persons who know the melody can see the accuracy of the results.

IV. RESULTS AND CONCLUSIONS

In this study 2 different tests are made after training ANN with the flute musical notes. Firstly, estimation of the note from melody which playing consecutive notes. The second forecast *Twinkle Twinkle Little Star* song notes. Accurate estimates were obtained in both studies.

![Fig. 9 Twinkle Twinkle Little Star song notes](image)

During the creation of the data matrix for ANN training, the used preprocessing methods, such as avoid repeating each window and take into account phase information can improve the performance.

It is observed that ANN is more suitable techniques than classical signal processing and filtering techniques [3, 9]. In future, the workings comparing classical and ANN techniques are advised. These workings are especially meaningful for generally Eastern music and Turkish music and musical instruments because of more detailed structure of their musical temperament.

![Fig. 10 The waveform for Twinkle Twinkle Little Star song (below) and ANN findings(above)](image)
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[13] Carlos Gershenson," Artificial Neural Networks for Beginners".


Applications of Fuzzy Logic in Building Performance Evaluation

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Abstract—The predictable and deterministic world of the past has been replaced by the uncertain, random, and disorderly world of today. Different attributes represent different dimensions of alternatives, which may not be easily represented on a quantitative scale, may not be directly measurable, and may be stochastic or fuzzy. Wide range applications of building performance evaluations are based on numerical grading, which have been conducted for comprehensive building analysis. However, expert evaluation, as a nature of human knowledge, tends to be vague or imprecise. Moreover, human decision-making needs a quick-response analysis based on the decision-maker’s intuition, judgement, and experience. In this study, in order to insert uncertainty and human knowledge to building performance evaluation systems, fuzzy logic method is proposed for vulnerability evaluation of building characteristics. For the first part of evaluation, fire safety performance evaluation model is proposed, and critical building components in terms of passive fire safety are identified including numerical and linguistic input variables.

Keywords—fuzzy logic, fuzzy expert system, construction project evaluation

I. INTRODUCTION

From the earliest periods of architecture and building, performance evaluations have been conditioned by rules, regulations, standards, and governance expert grading, which have been contradicting the creative basis of their practice [1]. On the other hand, new construction methods, resulting from new and unfamiliar materials, new organizations of functions and occupancy classes, new equipment in the buildings, or different activities facilitated within building occupancy introduce new complex interactions. As the interactions get more complex, existing building performance guidelines remain too generic to understand the relationships and they become less competent in evaluating performance of buildings. Moreover, rapid increase in the complexity and embedded information in building systems drastically limits the time available for making decisions. The inherent nature of construction projects tends to be uncertain and depends on a subjective judgment of decision makers [2]. Therefore, the single-criterion and simple decision-making requirements of the guidelines have given way to highly complex decision problems involving multitudes of variables, which may be stochastic, fuzzy, or at worst unknown [3]. On the other hand, human decision-making needs a quick-response analysis based on the decision-maker’s intuition, judgement, and experience. However, when the complexity of a system increases, the ability of human beings to make precise, but significant statements diminishes [4]. Therefore, the human reasoning usually gives results in approximate ranges [5]. In addition, the decision making in real-world situations is a complex subject with uncertainty and vagueness [2]. In order to insert human reasoning in building performance evaluation systems, fuzzy logic system is used as a decision making and evaluation method. Fuzzy logic helps to integrate uncountable, undefined, and uncertain information into the decision-making process by converting hidden information into workable algorithms.

II. PERFORMANCE EVALUATION OF BUILDINGS

The evaluation methods used in traditional occupational hazards in the construction industry were mainly qualitative or statistical approaches. In addition, construction experts tend to use a single crisp value during risk assessments, which may lead to inaccurate assessment results [6]. By the time knowledge is being transformed into their digital representations in all fields, performance evaluation of building parameters imported into automated code compliance checking systems. Computerized checklist systems have advantages for detecting building vulnerabilities faster, however, in terms of reflecting the diversity of evaluation methods, they are dependent to deterministic [7]. The deterministic approach of evaluation is the disadvantage of accurate performance evaluation in the uncertain nature of construction. Hence, the single-criterion evaluation prevents the integration of design objectives.

In integrated building design, architects and engineers develop building specifications together from an early stage of the project. Therefore, various key design objectives as performance evaluation determinants are needed to be assessed to take prevention measures in preliminary design stages. The multi-objective structure of building performance evaluation need to be analyzed and prioritized with respect to multiple attributes. The decision-making process consists activities of:

- studying the situation,
- organizing multiple criteria,
- assessing multiple criteria,
- evaluating alternatives based on the assessed criteria,
- ranking the alternatives,
- incorporating the judgements of multiple experts.
In multi-attribute evaluation system attributes are referred to as goals; and different attributes represent different dimensions of evaluating the alternatives [3]. Due to the dependency of evaluation system to expert opinion, the multi-objective performance evaluation systems are suitable to be expressed by linguistic variables. When people are asked to do subjective decision making on a subject in verbal categories rather than numerical categories, the consistency is improved and more accurate results are achieved [8]. Most words are inherently vague and depend on some arbitrary qualification for crisp application. Considering the operational and stochastic characteristics of construction projects and the fuzziness of multiple-objectives need to be considered for appropriate evaluation model [9]. Fuzzy logic, with less information and workability of linguistic terms, can absorb human knowledge without having to translate it into a complex mathematical model. In this research, the advantages and the challenges of evaluating building performance by using fuzzy logic is discussed. The method is proposed for quick-response performance assessment in the preliminary design phase, with an intelligible model for each project member. In the following parts of the study, the definition of fuzzy logic with fuzzy expert systems and hybrid fuzzy systems which combine other methodologies with fuzzy logic are explained.

A. Fuzzy Logic

Fuzzy logic is developed by by Zadeh (1965), on the idea that all things admit of degrees. The classical (Boolean) logic was expanded to consider the partial truth and all values between “completely true (1)” and “completely false (0)” (Zimmermann). In general, the design of fuzzy controllers consists of defining three parameters, the domain for the input and output of linguistic variables, the set and the type of membership function for each linguistic value. A linguistic variable differs from numerical variable since its values are not numbers but words or sentences in a natural or artificial language [2]. In the fuzzy logic system, the linguistic variables describe the vague concept of decision-making (e.g. good performance), while the membership functions define the shape of the fuzzy set. Several input parameters with corresponding subdivisions are combined with expert opinion to give an output value [10].

Fuzzy systems used in many areas such as data classification, imperfections detection and to support decision making. Fuzzy systems have advantages to evaluate performances by representing uncertainties. However, the extension of the system is done through the addition of new rules, which may be the disadvantage since the rules depend on the existence of experts. Therefore, for more complicated models, the fuzzy systems combined with other systems such as fuzzy expert systems, fuzzy neural network, fuzzy reasoning and fuzzy clustering to improve the decision-making capacities.

B. Hybrid Fuzzy Systems

In construction management research, it is observed that hybrid fuzzy techniques are widely adopted since they can better solve problems that fuzzy logic alone may not solve [2]. In order to integrate the uncountable, undefined, and uncertain information in decision-making process, fuzzy expert systems are used. Expert systems use domain specific knowledge to simulate the reasoning of an expert in the field in order to perform intelligent tasks [11]. Based on experts’ dependency on common sense when solving problems by using vague and ambiguous terms, the expert system is developed with five main steps [12]:

- specify the problem and define linguistic variables,
- determine fuzzy sets,
- construct fuzzy rules,
- encode the fuzzy sets and fuzzy rules to perform fuzzy inference,
- evaluate and tune the system.

![Fuzzy expert system model (Nilashi et al., 2011)](image)

In the fuzzification interface, the input variables are structured and fuzzified through membership functions, and the degree of belonging of input variables is determined. In fuzzy rule base module, if-then rules are set by experts by using linguistic values. Fuzzy if-then rules and fuzzy reasoning are the basis of fuzzy expert systems to structure the decision-making system. On the other hand, the consequence of each rule is computed by inference engine. Finally, in defuzzification phase, fuzzy output is converted to crisp output and the performance result is calculated by using membership degree of the output value [13].

On the other hand, for more complicated systems and decision processes fuzzy sets are combined with neural networks with learning and generalization capacity. Neural networks are strong in pattern recognition and automatic learning while fuzzy logic are strong in modeling of uncertainties.

III. APPLICATIONS OF FUZZY LOGIC IN BUILDING PERFORMANCE EVALUATION

Performance requirements for building systems such as serviceability, safety, security, comfort and functionality are often affected by various uncertainties. The definition of these uncertainties can be hardly described by traditional probabilistic methods. Moreover, translation of human needs, especially those concerning occupancy comfort to provide performance requirements often results in a vague and imprecise definition of the technical requirements. Thus, in addition to the natural randomness of basic variables, performance requirements may be considerably affected by fuzziness [14]. Fuzzy techniques have been increasingly applied to the research area of construction management discipline over the last decade [4]. Fuzzy logic and hybrid fuzzy techniques are
used applications of decision making, performance, evaluation, and modeling of building systems. In this study, fuzzy system application areas used for building systems are explained, as a decision support methodology to detect defects of projects in early stages. As one of the key building objectives, passive fire safety decision making fuzzification modules with input parameters are expressed.

A. Performance Evaluation of Building Systems

When compared to other industries, the construction industry subject to more risks due to the unique features of construction activities, such as long period projects including complicated processes together with dynamic organizational models [15]. Within the complicated process, in order to function more efficiently, the building performance systems must be integrated together. Systems must be compatible and share common information to eliminate multiple data entry. Based on this concept, the fuzzy expert system aims to control the building design input variables within the acceptable limits.

Fuzzy logic can be adopted for building systems to develop models and to make decisions and to evaluate the performance in a wide range of areas which are often viewed as complicated, uncertain, and ill defined. Moreover, fuzzy systems define the relationship between risk sources (input) and the consequences (output) by using knowledge base (fuzzy rules) [16].

The studies using fuzzy systems to evaluate building objectives have wide range of applications to support the decision making in construction field. When conducting the performance assessments, the severity factor should be taken as close as possible to objectives at the time of assessment [16]. Most of the fuzzy applications focused on time, cost, quality, and safety performance measures. Some of them are predicting potential cost overruns on engineering design projects [17], time cost trade off model [18], time-cost optimization [9], project scheduling [19], safety management [21]. Other researches considering planning and sustainability are dealing with acceptable building levels of environmental impact and socioeconomic characteristics of residential building [22], site layout and planning [21], sustainable housing decision support tool [23], performance of green buildings [24].

There are fuzzy systems based on building technology and information technology disciplines related with building thermal dynamic response [25], user acceptance and adaptation [26], car-parking guidance [27], thermal conductivity [28], heating control [29], however, these applications are limited. Furthermore, building design objectives are not interrelated to assess the comprehensive fuzzy performance assessment, although most the building performance objectives including fire safety, sustainability, cost effectiveness, security, maintainability, accessibility / circulation, structural stability / constructability and occupant activity include uncertainty with multi-criteria (Fig. 2). Thus, the definition of membership functions, linguistic variables and interdependency rule of input variables can be fuzzified to support acceptable building performance levels.

B. Performance Evaluation of Building Construction Parameters in Fire Safety

Fire safety, as one of the key objectives, is an important need, although it has a lower priority than other design objectives since not generating explicit benefit such as comfort or convenience [30]. In addition, it has low level of risk perceived from fire, however, the consequences of fire make it one of the most life threatening hazards that needs importance in performance evaluation. Fire safety evaluation systems are regarded as subjective and uncertain methods even if experienced experts conduct them [31].

Designing of fire prevention starts with the building design process. Therefore, important safety measures can be involved in the preliminary design phase by confining fire by construction parameters. In this process, architects lead both the architectural and fire safety concerns at the same time. The evaluation process including building parameters depends on designing a building in such a way that it is difficult for a fire to start and spread within. The construction parameters and their interrelationships are described in the Figure 3.

Accordingly, the measures to prevent fire spread through boundaries and through external fire spread comprise fire reaction of interior linings, structure separation and load bearing and door protection and closing. These common
parameters for both architectural and fire safety design can be expanded according to performance objectives and the detail level of assessment. The evaluation factors and the input variables for each parameter defines the database set for evaluation. The input variables of the building objectives that are generated in categorical functions with crisp numbers, and fuzzy membership functions with triangular membership functions form the database. The membership functions are need to be generated for each sub-parameter under the input parameter, such as resistance, integrity, insulation of structural members and providing fire stop joints in concealed and intersection spaces express structure separation performance assessment. The output membership function for each sub-parameter, parameter and building objective is required to have same number of severity levels to interrelate final linguistic value. The example of five scale risk assessment levels from the least severe level “low”, to the most severe level to “high”, and the intermediate levels “low-to-medium”, “medium”, and “medium to high” are represented in Figure 4.

![Membership functions for risk assessment](image)

Fig. 4. Membership functions for risk assessment (Tah & Carr, 2000)

The fuzzy system to assess building performance is rule-based model, so that the domain knowledge contains the rules. Rules are generated in the If-Then form to represent the expert’s reasoning process. For example, If “the interior lining are A1”; Then “the fire risk severity is Low”. The literature reviews are conducted to develop sub-parameter evaluation tables and the structured interviews are needed to include expert opinion. The success of the system relies on the ability to formalize and represent the knowledge within the applied field. The collected knowledge is subjective, incomplete, and ill-defined, based on expert experience, judgement and intuition.

IV. CONCLUSIONS

Fuzzy performance evaluation of building objectives provides an alternative method to regulation-based deterministic evaluation methodologies. In this paper, the limitation of studies for comprehensive fuzzy evaluation in construction field is criticized and uncertain characteristics of building objectives are emphasized. As an example, fuzzy methodology is described in relation to fire safety objective, by means of confining fire by construction. The performance evaluation model enables the project team members such as designers and engineers, entering the project data in terms of numerical and linguistic values and to detect imperfections in the form of severity levels to take necessary precautions. For the multi-objective building performance evaluation model, using hybrid fuzzy systems provides advantages with learning and generalization capacity, in order to define interdependency of parameters. Moreover, further research is required to test the applicability of method in terms of quick response assessment analyses.

REFERENCES


Abstract—The mining industry is a sector that hosts on site many of occupational health and safety risks from the search phase to the production and shipping. In case of failure to prevent these risks it is encountered high occupational accidents and diseases. In mining, the main thing is to produce according to constantly changing environmental conditions that’s why it differs from other business branches. In this situation in mining sector in determination of risks and obtaining projective measures correctly, the statisticall evaluation of the previous accidents is very important. For this purpose there can be found many learning systems that learn from the past and make estimations for the future. Therefore in this paper a classification model is constructed that makes estimation of the sum of injured employees in the mines according to some attributes. In this estimation model the amount of production, amount of production yield, total number of employees, amount of dynamite in kilos, amount of capsules, mast consumption and total number of injured are used as the attributes. Thus with this model estimation of injured employees is performed according to these attributions using MATLAB platform. For this study the database is used obtained from Turkish Hard Coal Enterprise that belongs to the years between 2010-2014. As the classification algorithms Linear Regression and Artificial Neural Networks (ANN) are used and the comparative results are evaluated.

Keywords—Learning System, Classification Model, Mine Industry, Machine Learning Algorithms

I. INTRODUCTION

As occupational safety is a concept of engineering, all steps for prevention of occupational accidents carry within itself the stages that require engineering solutions. However although there is a rapid development of science, technology, development and industrialization it can not be said these developments are exactly reflected to the process of working life, occupational health and safety. Within industrial sectors mining industry is a sector that hosts on site many of occupational health and safety risks from the search phase to the production and shipping. According to the data obtained from Social Security Administration of Turkish Republic in 2012, 11.79% of work accidents occurred in coal mining in Turkey [1]. In mining sector due to the occupational accidents each year many people come to a state that can not work and many deaths occur. It can be seen from the accident statistics in mining across the country, especially in underground coal mine methane gas explosion and uncontrolled caving are the major accidents [2].

Source of hazards in mines can be given as methane content in coal seam, uncontrolled caving due to lack of support, spontaneous combustion in coal seam, gas poisoning or gas suffocation, coal or metal dust explosion, haulage, drilling and blasting, and sub-contract system [3]. In this situation in mining sector it is very important to be aware of the possible risks and to take precaution because these can save lifes. In determination of risks and obtaining projective measures correctly, the statisticall evaluation of the previous accidents is foremost. For this purpose there can be found many learning systems that learn from the past and make estimations for the future ([2],[4]-[6]).

In this paper a classification model is constructed that makes estimation of the sum of injured employees in the mines according to some attributes. In this estimation model the amount of production, amount of production yield, total number of employees, amount of dynamite in kilos, amount of capsules, mast consumption and total number of injured are used as the attributions. For this study the database is used obtained from Turkish Hard Coal Enterprise that belongs to the years between 2010-2014. The rest of the paper is organized as follows: In the second section hard coal mining in Turkey is considered. In the third section material and methods are given, in the fourth section experimental results are given and in the final part conclusion is given.

II. HARD COAL MINING IN TURKEY

Hard Coal is a fossil fuel and it is used as a source of energy for hundreds of years. As an energy source coal has many advantages and is being used for electricity production. It is one of the most abundant sources of energy, more so than oil and natural gas. According to the 2010 BP Statistical Energy Survey, Turkey had end 2009 coal reserves of 1814 million tonnes, 0.21% of the world total. The most important
coal reserves of our country are located in Zonguldak Basin [7]. Hard coal reserves in Turkey are as given in Table 1. Zonguldak Basin where deep in underground coal mining has been made has a complex geological structure. That’s why instead of full mechanization coal production is mainly carried out on the basis of the labor-intensive manpower.

### III. Material and Methods

In this paper a classification model is constructed that makes estimation of the sum of injured employees in the mines according to some attributes. The database is used obtained from Turkish Hard Coal Enterprise that belongs to the years between 2010-2014. Linear Regression (LR) and Artificial Neural Networks (ANN) are used as the classification algorithms.

**A. Material**

A database is used obtained from Turkish Hard Coal Enterprise that belongs to the years between 2010-2014. It includes the data from Turkey Hard Coal Enterprises. The data includes eight attributes such that amount of production, amount of production yield, total number of employees, amount of dynamite in kilos, amount of capsules, mast consumption and total number of injured. The database includes five years data that belongs to Turkish Hard Coal Enterprise. A sample of the database for 2010 is given in Table 2.

**B. Methods**

In this paper to make estimations for the future from the data in hand a classification model is developed by using two different algorithms. These algorithms are Linear Regression and Artificial Neural Networks (ANN). Classification is a supervised machine learning algorithm. In a supervised algorithm the database is split into two sets such as a training set and a test set. The model is constructed according to the training set which class values are available. The test set values are used to test the performance of the constructed model.

#### 1) Linear Regression:

Linear regression is a predictive analysis and it is used to obtain the relationship between one dependent (class) and one or more independent variables (attributes). The objective of this analysis is fitting a single line through a set of data points and finding the equation representing the line [8]. Then according to the line equation obtaining the unknown dependent variable value by putting the known independent variable values. In the simplest form of the linear regression there are only one dependent and only one independent variable. The form of the model can be given as in Eq.1

\[ y = ax + b \]  

(1)

where y is the dependent variable (estimated), a is the regression coefficient, b is the constant and x is the independent variable. In multivariate Linear Regression there are more than one independent variables as can be seen from Eq. 2.

\[ y = \hat{b} = \sum_{i=1}^{k} c_i x_i \]  

(2)

where y is the dependent variable (estimated), a is the regression coefficient, b is the constant and \(x_i\) \(i = 1,...,k\) are the independent variables.

#### 2) Artificial Neural Networks (ANN):

Artificial Neural Network is a learning system that can learn from data samples known as training examples and then develop a system which can learn from these training examples. Working of this process is similar to a simple simulation of the working of the human brain. Neuron is the basic part of ANN and its working principal can be seen in Fig.1. The sum of the weighted inputs to a neuron is applied to an activation function then an output is produces according to that activation function [9].

### Table I: Coal Reserves in Turkey (ton)

<table>
<thead>
<tr>
<th>Reserve Type</th>
<th>Kozlu</th>
<th>Uzülmez</th>
<th>Karadon</th>
<th>TTK Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reserve Type</td>
<td>Mining</td>
<td>Smelting</td>
<td>Coke</td>
<td>Total</td>
</tr>
<tr>
<td>Antakya</td>
<td>404.060</td>
<td>1,763</td>
<td>3,146</td>
<td>2,825</td>
</tr>
<tr>
<td>Apparent</td>
<td>169.268</td>
<td>6,374</td>
<td>317</td>
<td>324</td>
</tr>
<tr>
<td>Possible</td>
<td>115.052</td>
<td>15.859</td>
<td>309</td>
<td>211</td>
</tr>
<tr>
<td>Potential</td>
<td>121.535</td>
<td>7,883</td>
<td>4,795</td>
<td>324</td>
</tr>
<tr>
<td>Total</td>
<td>400.060</td>
<td>6,374</td>
<td>317</td>
<td>2,825</td>
</tr>
</tbody>
</table>

### Table II: A Sample Database for 2010

<table>
<thead>
<tr>
<th>Year</th>
<th>Months</th>
<th>Production</th>
<th>Employee</th>
<th>Total Injured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>263.01</td>
<td>3.48</td>
<td>10.87</td>
<td>23.70</td>
</tr>
<tr>
<td>Feb</td>
<td>245.52</td>
<td>3.35</td>
<td>10.80</td>
<td>22.41</td>
</tr>
<tr>
<td>Mar</td>
<td>283.98</td>
<td>3.48</td>
<td>10.78</td>
<td>25.02</td>
</tr>
<tr>
<td>Apr</td>
<td>299.74</td>
<td>3.49</td>
<td>10.88</td>
<td>24.08</td>
</tr>
<tr>
<td>May</td>
<td>313.50</td>
<td>3.42</td>
<td>10.68</td>
<td>21.94</td>
</tr>
<tr>
<td>Jun</td>
<td>320.64</td>
<td>3.32</td>
<td>10.64</td>
<td>23.12</td>
</tr>
<tr>
<td>Jul</td>
<td>322.14</td>
<td>3.25</td>
<td>10.48</td>
<td>21.73</td>
</tr>
<tr>
<td>Aug</td>
<td>283.02</td>
<td>3.01</td>
<td>10.50</td>
<td>18.55</td>
</tr>
<tr>
<td>Sep</td>
<td>182.57</td>
<td>3.01</td>
<td>10.20</td>
<td>17.50</td>
</tr>
<tr>
<td>Oct</td>
<td>204.93</td>
<td>3.12</td>
<td>10.19</td>
<td>19.49</td>
</tr>
<tr>
<td>Nov</td>
<td>166.72</td>
<td>2.86</td>
<td>10.16</td>
<td>15.78</td>
</tr>
<tr>
<td>Dec</td>
<td>229.41</td>
<td>3.30</td>
<td>10.83</td>
<td>21.96</td>
</tr>
</tbody>
</table>
IV. EXPERIMENTAL RESULTS

In this study three different experimental studies are performed. Two of them are regression analysis and one of them is ANN application. Two different regression analyses are performed. One of them is simple one variable regression analysis and the other one is multivariate regression analysis.

A. Linear Regression

Two different regression analyses are performed such as simple one variable regression analysis and multivariate regression analysis. In one variable regression analysis each attribute in the database given in Table II is related with the class information that is the total number of injured. With this analysis it is aimed to show the relationships between each attribute with the total number of injured. Thus it can be seen that which attribute most affects the estimation accuracy. The MATLAB simulation of this regression analysis can be seen in Fig. 2 and the results are given in Table III.

In multivariate regression model the six attributes such that the amount of production, amount of production yield, total number of employees, amount of dynamite in kilos, amount of capsules and mast consumption are used. Then using these attribute values as the variables multivariate regression analysis is performed and according to the obtained regression model the linear line is given in Eq. 3

\[ y = 1.859526 + 1.2429 \times x_1 - 0.039297 \times x_2 + 0.00306 \times x_3 + 0.3781 \times x_4 + 0.09853 \times x_5 - 4.3550 \times x_6 \]  

(3)

number of injured employees are estimated. The \( R^2 \) for this analysis is determined as 0.733. With respect to the regression equation given in Eq. 3 when there is an increase in the amount of production, total number of employees, amount of dynamite, amount of capsules an increase is also observed in the number of injured. In contrast when an increase is observed in the amount of production yield and the mast consumption it is observed a decrease in the number of injured.

Residual plots help to discover errors, outliers, or correlations in the model [10]. Among the several residual plots the histogram plot in Fig. 3 that is the simplest one and the probability plot in Fig. 4 are preferred.

![Fig. 1 Working process of a simple neuron](image)

**TABLE III**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Production amount</th>
<th>Production yield</th>
<th>Total employee</th>
<th>Explosive (kilos)</th>
<th>Number of capsules</th>
<th>Mast costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R^2 ) Value</td>
<td>0.6936</td>
<td>0.0858</td>
<td>0.0106</td>
<td>0.0106</td>
<td>0.0106</td>
<td>0.6192</td>
</tr>
</tbody>
</table>

![Fig. 2 MATLAB simulation of the one variable regression analysis](image)

According to the results given in Table III the amount of production is the most effective factor in determining the total number of the injured and then the mast consumption are the second important factor. The other attributes that are amount of production yield, total number of employees amount of dynamite and amount of capsules are not effective in determining the total number of injured.

![Fig. 3 The histogram plot of residuals for the multivariate linear regression model](image)

According to this histogram it can be seen that production levels, total number of employee, explosive used in kilos and number of capsules used have peaks. Thus it can be
understood that these attributes are the most effective ones in the model.

Fig. 4 The probability plot of residuals for the multivariate linear regression model

The placement of the data dots as shown in the graph in Fig. 4 is not a linear line but it can be approached in such a linear line shows that the model is significant and the data has a positive and high correlation on the total number of injured.

B. Artificial Neural Networks (ANN)

In this classification model MATLAB ANN Toolbox (Fig. 5) is used. The six attributes given in Table I are all used as the inputs and the class is used as the output of the ANN configuration given in Fig. 6.

This configuration has three layers basically such that input layer, hidden layer and output layer. Input layer has six neurons, hidden layer has ten neurons and the output has one neuron.

Fig. 6 The ANN configuration of the classification.

According to the results best performance is obtained during the 26th epoch (Fig. 7).

Fig. 7 Mean squared error versus epochs.

The evaluation of the constructed network is as given in Fig. 8. The plot of regression is given in Fig. 9.
V. CONCLUSIONS

In this study using the data obtained from Turkish Hard Coal Enterprise that belongs to the years between 2010-2014 three different classification models are constructed. The two of them are linear regression models and the other one is the AAN model. In each model amount of production, amount of production yield, total number of employees, amount of dynamite in kilos, amount of capsules, mast consumption are used as the attributes and the total number of injured is used as the class information (the estimated parameter).

According to the simple linear regression model results given in Table III the amount of production is the most effective factor in determining the total number of the injured and then the mast consumption are the second important factor. The other attributes that are amount of production yield, total number of employee, amount of dynamite and amount of capsules are not effective in determining the total number of injured.

According to the multivariate linear regression model results when there is an increase in the amount of production, total number of employees, amount of dynamite, amount of capsules an increase is also observed in the number of injured. In contrast when an increase is observed in the amount of production yield and the mast consumption it is observed a decrease in the number of injured. According to this histogram it can be seen that production levels, total number of employee, explosive used in kilos and number of capsules used have peaks. Thus it can be understood that these attributes are the most effective ones in the model. And also the probability plot in Fig.4 shows that the model is significant and the data has a positive and high correlation on the total number of injured. The ANN classification model results are also significant.

REFERENCES

Hybrid Assessment by Modified Translated Multiplicative and McCulloch-Pitts Neurons Models for Monk’s Problem

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Abstract— In this study, a solution to the Monk’s problem (Monk’s 2- M2) employing a single neuron dependent on rules which use either modified translated multiplicative (πm) neuron or McCulloch-Pitts neuron model, is proposed. Since M2 problem is similar to N-bit parity problem, first N-bit parity problem is examined with translated multiplicative (πt) neuron. Then this architecture is modified for M2 problem. Also, McCulloch-Pitts neuron model is used to increase classification performance. When the result of proposed only one πm neuron model that is not required in any training stage and hidden layer is compared with the other approaches, it shows satisfactory performance.

Keywords— Machine learning; Translated multiplicative neuron model; Modified translated multiplicative neuron model; N-bit parity problem; Monk’s problems

I. INTRODUCTION

Translated multiplicative neuron (πt-neuron) is primarily used to the N-bit parity problem. N-bit parity problem is an approach to test neural network architectures and learning algorithms. The N-bit parity problem is considered as a very hard problem to be solved by neural networks, because a single ‘flip’ of a bit in the input string requires a complementary classification. The N-bit parity problem is a generalization of the ‘exclusive-OR’ (XOR) problem. N-bit parity problem can be explained as follows. Let x = [x₁, …, xₙ]T is N-bit binary vector and xᵢ ∈ {0,1} (i = 1, …, N). The parity generator function which is stated as shown in Eq.1, can be determined the parity as follows:

\[ p(x) = \begin{cases} 0, & \text{if } \sum_{i=1}^{N} x_i \text{ is even} \\ 1, & \text{otherwise.} \end{cases} \] (1)

There are many neural network architectures applied in N-bit parity problem [1-8]. Kim et al. proposed a method of improving the learning time and convergence rate to exploit the advantages of ANN and fuzzy theory to neuron structure. Their method is applied to the XOR and N-bit parity problems [6]. But, Iyoda et al. make a comparison between neural architectures for the N-bit parity problem [1]. The comparison result shows that πt neuron model is not required any hidden neurons and learning algorithm. πt neuron model is called translated multiplicative neuron model. It uses threshold activation function. Since πt neuron model stems from multiplicative neuron model, then several multiplicative neurons which have been proposed [9, 10, 11] can be examined to comprehend πt neuron model. The model is defined as follows:

\[ v = b \prod_{i=1}^{N} (x_i - t_i) \quad y = f_{th}(v) \] (2)

where, b ∈ R and tᵢ ∈ R (i = 1, …, N) which are the neuron’s adjustable parameters, are bias and weights, respectively. The neuron’s output is y.

The threshold activation function \( f_{th} : \mathbb{R} \rightarrow \{0, 1\} \) is defined as follows:

\[ f_{th} = \begin{cases} 1, & v \geq 0 \\ 0, & v < 0 \end{cases} \] (3)

In fact, πt-neuron model which is shown in Figure 1 is inspired from McCulloch-Pitts. McCulloch-Pitts neuron model is given by the following equation:

\[ v_m = w_0 + \sum_{i=1}^{N} x_i w_i, \quad y = f_{th}(v_m) \] (4)

where, \( w_0 \) is bias and \( w_i \) are the weights.

Comparing Eq. 4 with Eq. 2, \( w_0 \) is equivalent to b and \( w_i \) are equivalent to \( t_i \) parameters. The parameters of multiplicative \( \pi_t \) neuron, which uses to threshold activation function, are defined as:

\[ 0 < t_i < 1 \quad (i = 1, \ldots, N), \text{ If } N \text{ is even then } b < 0, \text{ If } N \text{ is odd then } b > 0. \]

If the same activation function is used in the Eq.2 and Eq.4, the mathematical procedure’s complexity is equivalent of these two models. Table 1 and Table 2 show the solutions of 2-bit XOR parity problem and 10x10-bit parity problem’s. b and all \( t_i \) parameters ([t₁, ..., tᴺ]) are selected as constants: -24 and 0.8, respectively. Iyoda et al. proved that the
translated multiplicative πt neuron model can solve the N-bit parity problem for ∀ N ≥ 1 [1].

![Figure 1. πt- Multiplicative neuron model](image)

An N-bit Parity problem can easily be solved by only one πt neuron using threshold activation function and parameters defined in certain intervals. This approach has the lowest process complexity, which is presented between neural network solutions so far [1]. Therefore, modified translated multiplicative (πm) neuron or McCulloch-Pitts neuron model, is proposed for solution of Monk’s M2 problem which has a nonlinear relationship similar to XOR problem. In Eq. 2 and Eq. 4, all biases and weights are chosen as constants with their optimum values. Since, they are chosen as constants; there is no need any learning stage for the both networks. The main contribution of the study that it presents modified translated multiplicative neuron model to solve Monk’s M2 problem by expressing it as an N-bit parity problem.

Table 1. Solution of 2-bit XOR Parity Problem

<table>
<thead>
<tr>
<th>x1</th>
<th>x2</th>
<th>y</th>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
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<td>1</td>
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</table>

Table 2. Solution of 10x10-bit Parity Problem

<table>
<thead>
<tr>
<th>x1</th>
<th>x2</th>
<th>x3</th>
<th>x4</th>
<th>x5</th>
<th>x6</th>
<th>x7</th>
<th>x8</th>
<th>x9</th>
<th>x10</th>
<th>y</th>
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<tbody>
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In the following section, Monk’s problem is presented. Previous studies in Monk’s problem are given in Section 3. The πm neuron model and results obtained from the application of either one πm neuron model or one McCulloch-Pitts neuron model to Monk’s M2 problem are given in Section 4.

II. DESCRIPTION OF MONK’S PROBLEM

An artificial robot named as Monk’s problem has six attributes that is defined by [12]:

- Problem M1: If head shape and body shape have same value or jacket color is red, this problem belongs to M1 (head shape = body shape or jacket color = red).
- Problem M2: If exactly two of six attributes of robot have their first value, this problem belongs to M2.
- Problem M3: If jacket_color is green and holding is sword or jacket_color isn’t blue and body_shape isn’t octagon, it belongs to M3 ((jacket_color = green and holding = sword) or (jacket_color ≠ blue and body_shape ≠ octagon)).

Data which are taken from 6 different places of the artificial robot must be rearranged to simulate to the parity rule. The arrangement is done by the following statements:

- Problem M1: has_tie \( \in \{0000, 0001\} \)
- Problem M2: holding \( \in \{0000, 0001, 0010, 0011\} \)
- Problem M3: has_tie \( \in \{0000, 0001\} \)

As it is seen above, decimal values are given to attributes for each point of the robot. These decimal values are converted to 4 bit binary number system. To adjust the data according to N-bit parity rule, each decimal value is decreased for one, and then the decreased decimal number is converted to its binary value.

III. OTHER STUDIES RELATED WITH MONK’S PROBLEM

Thurn et al., summarize the comparison of different learning techniques in a report which was performed at the 2nd European Summer School on Machine Learning, held in Belgium during summer 1991 [12]. A variety of symbolic and non-symbolic learning techniques are compared on Monk’s problems. In Table 4, only the comparison results of Monk’s
M2 problem with this study are given. One significant characteristic of this comparison is that it was performed by a collection of researchers, each of whom was an advocate of the technique they tested. Here some algorithms that have recognition rate more than this study are explained in this section. Since Thrun et al. give brief description about their studies [12], special properties of the algorithms e.g. rules that are used in their algorithms or other things which are based on neural networks will reemphasize in the following:

**AQ17 Algorithms.** AQ17-DCI algorithm is based on AQ learning programs. Here is a brief description of the AQ algorithm:
1. Select a seed example from the set of training examples for a given decision class.
2. Using the extend against operator, generate a set of alternative most general rules (a star) that cover the seed example, but do not cover any negative examples of the class.
3. Select the “best” rule from the star according to a multi-criteria rule quality function (called LEF – the Lexicographical Evaluation Function), and remove the examples covered by this rule from the set of positive examples yet to be covered.
4. If this set is not empty, select a new seed from it and go to step 2. Otherwise, if another decision class still requires rules to be learned, return to step 1, and perform it for the other decision class.

AQ17-DCI uses 2 rules for Class 0 and 1 rule for Class 1.

**Backpropagation and Backpropagation with weight decay.** There were 17 input units, all having either value 0 or 1 corresponding to which attribute-value was set. All input units had a connection to 2 hidden units, which itself were fully connected to the output unit. An input was classified as class member if the output, which is naturally restricted to (0; 1), was ≥ 0.5. Training took between ten and thirty seconds on a SUN Sparc Station. On a parallel computer, namely the Connection Machine CM-2, training time was further reduced to less than 5 seconds for each problem. The following results are obtained by the plain, unmodified backpropagation algorithm. After 90 training epochs, the system performance was reached to 100% accuracy. Weight decay widely used technique often prevents backpropagation nets from overfitting the training data and thus improves the generalization. With weight decay α=0.01 Thrun improved the overfitting the training data and thus improves the technique often prevents backpropagation nets from overfitting the training data.

The system performance is 88.166%.
The following rules and threshold activation function given in Eq.3 are used for both πm and McCulloch-Pitts neuron models:

- Rule 1: IF (x1=3 or x2=3 or x4=3 or x5=3) THEN b=2 use Eq.2 ELSE b=2 use Eq.4
t Only Rule 1 is used, the 125 of 169 data are correctly classified.
The system performance is 73.964%.
- Rule 2: IF x5=4 THEN b=2 use Eq.2
If Rule 1 and Rule 2 are used together, 143 of 169 data are correctly classified.
The system performance is 84.615%.
- Rule 3: IF x5=4 and ((x1 = x2 = x3 = 1 and x4 ≠ 1) or (x1=3 and x2 ≠1 and x3 ≠ 1 and x4 ≠ 1 and x6 ≠ 1) or (x1=2, 3 and x2 = 2, 3 and x3 ≠ 2, 3 and x4 = 2, 3 and x6=2)) THEN b=2 use Eq.2 ELSE b=2 use Eq.2
If Rule 1, Rule 2 and Rule 3 are used together, 149 of 169 data are correctly classified. The system performance is 88.166%.

- Rule 4: IF (x1=3 or x2=3 or x4=3 or x5=3) and ((x1= x2= x3 = x6=1) or (x1=3 and x2 = 2, 3 and x3 = 2, 3 and x4 = 2, 3 and x5 = 2, 3 and x6=2) or (x1 = 2, 3 and x2 ≠ 2 and x3 ≠ 2 and x4 ≠ 5 and x6 = 1) or (x1 = 2 and x2 = 3 and x3 = 2 and x4 ≠ 1 and x6 ≠ 1) or (x1 ≠ 3 and x2 ≠ 2 and x3 = 1 and x4 = 1 and x6 ≠ 2) or (x1 =

**IV. MODIFIED TRANSLATED MULTIPLICATIVE (Tm) NEURON MODEL.**

Only M2 problem is similar to parity problem among these three Monk’s problems. So, πm neuron model that is formed by the algorithm of π is applied to M2 problem. When πm neuron model is used stand alone, no good classification performance is obtained. Therefore, πm or McCulloch-Pitts neuron models alternatively are used according to the rules.

Data matrix that has size of 169x7 is obtained from ftp server of University of California, Irvine [13]. According to robot’s attributes, 64 of the data produced the output 1 while the rest produced output 0. The first experiment is done for examining the πm neuron model using 169 data matrix. The b and ti parameters of πm neuron model are chosen -1 and 0.5, respectively (b=-1, 1,...,n = 0.5, where N=24). Since the robot has 6 attributes and each of them is represented by 4-bit binary number, the model has 24 inputs. For the first classification, 105 of the data have been correctly classified with 62.130% success. While 115 out of 169 data are already 0, the 62.130% system performance is not satisfying for the classification given above. If all the outputs of the model are assumed to be 0, anyway 68.047% performance is obtained. The input data are examined to get a better solution than above. When any of x1, x2, x4, and x5 has the value “3” in decimal number system, it is observed that πm neuron model is not good in classifying according to N-bit parity rule. So, some changes in algorithm are made by adding rules to multiplicative πm neuron model. This neuron model is named as modified translated multiplicative (Tm) neuron model. Here, b parameter in πm neuron model is chosen different from π that is used for N-bit parity problem.

The following rules and threshold activation function given in Eq.3 are used for both πm and McCulloch-Pitts neuron models:

- Rule 1: IF (x1=3 or x2=3 or x4=3 or x5=3) THEN b=2 use Eq.2 ELSE b=2 use Eq.4
- Rule 2: IF x5=4 THEN b=2 use Eq.2
- Rule 3: IF x5=4 and ((x1 = x2 = x3 = 1 and x4 ≠ 1) or (x1=3 and x2 ≠1 and x3 ≠ 1 and x4 ≠ 1 and x6 ≠ 1) or (x1=2, 3 and x2 = 2, 3 and x3 ≠ 2, 3 and x4 = 2, 3 and x6=2)) THEN b=2 use Eq.2 ELSE b=2 use Eq.2
- Rule 4: IF (x1=3 or x2=3 or x4=3 or x5=3) and ((x1= x2= x3 = x6=1) or (x1=3 and x2 = 2, 3 and x3 = 2, 3 and x4 = 2, 3 and x5 = 2, 3 and x6=2) or (x1 = 2, 3 and x2 ≠ 2 and x3 ≠ 2 and x4 ≠ 5 and x6 = 1) or (x1 = 2 and x2 = 3 and x3 = 2 and x4 ≠ 1 and x6 ≠ 1) or (x1 ≠ 3 and x2 ≠ 2 and x3 = 1 and x4 = 1 and x6 ≠ 2) or (x1 =
3 and \( x_2 = x_5 = x_6 = 1 \)) THEN \( b = -2 \) use Eq.2 ELSE \( b = 2 \) use Eq.2.

If Rule 1, Rule 2, Rule 3 and Rule 4 are used together, 154 of 169 data are correctly classified. The system performance is 91.124%.

- Rule 5: IF \((x_1 \neq 3 \text{ or } x_2 \neq 3 \text{ or } x_4 \neq 3 \text{ or } x_5 \neq 3)\) THEN \( b = -2 \) use Eq.4

If Rule 1, Rule 2, Rule 3, Rule 4 and Rule 5 are used together, 163 of 169 data are correctly classified. The system performance is 96.45%. In the all rules, weights of the neuron models are chosen as 0.5.

A study is carried out to examine the performance of \( \pi_m \) neuron model parameters \( b \) and \( t_i \) as shown in Table 3. To get the best performance, the parameters \( b \) and \( t_i \) are to be chosen in M2 problem as follows:

- \( b: \pm 1 \text{ and } t_i: 0.3 \)
- \( b: \pm 2 \text{ and } t_i: [0.5-0.6] \)
- \( b: \pm 3 \text{ and } t_i: [0.8-0.9] \)

Table 3. Performances due to different \( b \) and \( t_i \) values

<table>
<thead>
<tr>
<th>( b )</th>
<th>( t_i )</th>
<th>Performance (%)</th>
<th>( b )</th>
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<th>Performance (%)</th>
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In addition to performance sequence of previous studies on Monk’s problem, \( \pi_m \) and McCulloch-Pitts neuron models proposed in this study are given in Table 4. The results obtained in this paper have higher performance when compared to the some of the studies given in Table 4. Studies supplying 100% performance for M2 problem are already known. This paper proposes a new approach which is called \( \pi_m \) neuron model. Moreover, 6 individual rules can be defined for the remaining 6 data, which are not correctly classified to make system performance 100%.

Table 4. The performance sorting for Monk’s M2 problem of different methods

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V. CONCLUSIONS

Modified translated multiplicative neuron which is inspired by the architecture of translated multiplicative neuron that is an effective ANN model in solving N-bit parity problem and McCulloch-Pitts neuron models are applied to Monk’s M2 problem. The 100% classification performances of studies given in Table 4 utilize hidden layer in ANN architecture such as the Backpropagation and Cascade Correlation models. The
proposed model consists of only one neuron. While AQ17-DCI algorithm uses 3 rules for obtaining 100% system performance, unfortunately the proposed model uses 5 rules with 96.45% performance. Six additional rules can be individually defined for the remaining 6 data, which are not correctly classified for accomplishing 100% performance. Since the weights and bias are optimally selected, the proposed model does not require learning stage.

REFERENCES

A Model Proposal for Improving the Efficiency of Facility Layout in Emergency Service in Faculty of Medicine

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Abstract— Facility layout which increases productivity and provides the most effective way to run the organization, is used both determine the location of departments, assistant services, facilities and edit this sections. There are numerous studies in the literature for the solution of facility layout’s problems. We have observed that the heuristics are preferred in some of these solutions. We used data mining in this study. Data mining continues to offer new horizons, perspectives and new methods in a new area every day. The basic objective of this study is to develop a model of the layout for the purpose of improving the emergency department’s functionality, the quality of patient care, the satisfaction of patient and employee. Firstly in this study data warehouse was created by using data of the past year in the hospital information system. Data warehousing is the entry of the association analysis model. Then a system will be develop to solve the problem using association analysis with Apriori association analysis which is one of the methods of data mining. The application of the study is carried out in Kirikkale University Faculty of Medicine Hospital. The goal of this study to develop a model proposal through utilizing the method of Facility layout techniques for emergency department which will be designed according to way of intervention on patients.

Keywords— Apriori Algorithm, Association Analysis, Data Mining, Emergency Department, Facility Layout Problem

I. INTRODUCTION

Data mining is process that various advance data analysis based on statistics and artificial intelligence are used by way of visual programming interface in order to find out hidden patterns and relations in huge data stacks. Data mining algorithms include statistical algorithms, mathematical algorithms and artificial intelligence algorithms (such as neural networks, decision trees, association rules) together.

Emergency department where data mining technique was applied is the first line in hospitals to face emergency patients. As a major function of emergency department, when a patient comes to the emergency department, the emergency department personnel perform a triage procedure and then transfer the patient to associated departments for treatment [1]. For patients waiting in the emergency services, delay in the medical examinations decrease the quality of service and customer satisfaction. At the emergency services these factors are of much more importance since patients who have risky healthy come emergency department. While taking care of patients, hospital staff, materials and flow of information between emergency service departments must be quick. In this regard layout is important.

In this study after receiving the necessary data from the information systems department of the Emergency Department in Kirikkale University Faculty of Medicine Hospital, data correction and data categorization work was done. Then the data table was converted into text file format that accepted by the apriori software format. After the data preparation stage, apriori algorithm was applied on the data which was categorical structure according to the predetermined support and confidence value and association rules was obtained by using SPSS Clementine software. Then the desired rules were generated from large item sets and then these association rules were used as a reference during the decision-making process for developed algorithm. This algorithm was applied on apriori algorithm’s results. Finally alternative facility layout planning was created.

Data mining algorithms have been used in various Facility Layout Problem in literature review. K-means clustering algorithm is applied to evaluate supermarket’s layout Larson et al.[2]. Ay and Çil [3], in their study, used apriori algorithm and multidimensional scaling to acquire relational database. Kundu and Dan [4] used genetic algorithm so as to cope up with facility layout problems. The aim of Altuntas and Selim’s study [5] is to propose new weighted association rule-based data mining approaches for facility layout problem. In Cil[6]’s study, different weighted association rule-based data mining approaches was applied to facility layout problem. Lee [7] offers an integrated model that forecasts the total walking time of a passenger by simulation and searches for a near-optimal layout by ant colony optimization. Aiello et al. [8] offers in their study a new multi objective genetic algorithm for dealing with unequal area facility layout problems. In Ozcan and Esnaf’s study[9], a mathematical model is propose based on association rule mining for store layout problem which involves the identification of the position of products and product categories which are shown in-store shelves. Yener [10] aims to find an interior design of a warehouse that is minimizing the costs occurs while orders gathering within the main distribution warehouse which is performing in retailer
sector. Performances of different warehouse designs obtained via different methods are examined with the aid of simulation techniques. In the workshop, data mining techniques which have association rules are also benefited from. Gonçalves and Resende [11], in their study propose a biased random key genetic algorithm for the unequal are a facility layout problem where a set of rectangular facilities with given area necessities has to be placed, without aliasing, on a rectangular floor space. Arulkumar and Saravanan used to solve the layout problem Artificial Bee Colony algorithm and Particle Swarm Optimization algorithms in their paper [12]. In Aktepe et al.’s study [13], association analysis which is one of the data mining technique and VIP-Plant Optimization was used to develop a new proposal of facility layout for a shopping center. In paper of Lin and Guan [14] a hybrid algorithm based on variable neighborhood search and ant colony optimization is pro-posed to solve the single row facility layout problem.

Studies implemented FLP and Data mining in hospital are very little in literature review. The contribution of paper of Yeh [15] is a new framework which is named annealed neural network. Aim of framework is to find vying solutions for the FLP efficiently. This framework take place the integration of Hopfield neural networks and simulated annealing. A Hopfield neural network is a representation model of the layout problem and simulated annealing is a search algorithm for finding the optimum or near optimum solutions. In Cakar’s PhD thesis [16] genetic algorithm is used to optimize the emergency department’s layout.

In the second section, methodology which is used in this study was mentioned. Studies which were done, developed algorithm, new facility layout which was generated were explained under application title that was explained in the third section. In the fourth section, summary of study was explained and improvement acquired was expressed numerically.

II. METODOLOGY

A. Data Mining

Data mining is the process of finding of information which is unseen from a big data. Data mining, analyzing the data from different source and transform it meaningful information [17]. Data mining is also named as knowledge discovery process, knowledge extraction, data analysis or knowledge mining from data.

Several techniques and algorithms such as Classification, Clustering, Regression, Artificial Intelligence, Neural Networks, Association Rules and Decision Trees are used for information exploration from databases [19]. One of the techniques is clustering which is used to describe the object of similar classes. The clustering technique defines the classes and assigns each object to a particular class. Classification widely used data mining technique, to develop a class and learning. Most frequent item in the large data set is found by association analysis. The main aim is to release interesting correlation and association between a big data set [17]. Regression analysis can be used to model the relationship between one or more independent variables and dependent variables. In data mining independent variables are attributes which is known and response variables are what we want to forecast. Neural network implies a set of connected input or output units and each connection has a weight present with it. Neural networks have the significant ability to derive meaning from complicated or indefinite data and can be used to acquire patterns and find trends that are too complicated to be noticed by either humans or other computer techniques [18]. Decision tree is one of the most important classification methods. Decision tree is a method used to divide data sets including more registries into smaller data sets via an array of decision rules. Artificial intelligence is capability that a computer or a robot controlled by computer carries out various activities like intelligence living creature.

B. Association Analysis in Data Mining

Association analysis, one of the most important and well researched techniques of data mining, was first introduced in study of Agrawal et al. [19]. The association rule algorithm is commonly used to identify relationships between items or features that occur synchronously in a database. The Apriori algorithm [20] is widely used to mine frequent item sets and learning association rules in a datamining field. It seeks to generate the desired rules from large item sets and then uses these association rules as a reference during the decision-making process. The Apriori algorithm is usually divided into two separate steps. First, minimum support is applied to find all of the frequent item sets in a database. Second, these frequent item sets and the minimum confidence constraint are used to form rules [21]. Association rules are rules presenting association or correlation between item sets.

C. Apriori Algorithm used for Association Analysis

Apriori algorithm the most popular algorithm which is used for the association rules discovery. The algorithm's name comes from the word "before (prior)".Because this algorithm receives information from a previous step. Apriori algorithm’s steps are given below:

- Determination of the number of minimum support and the value of minimum confidence.
- Finding the value of support of the each element in the element sets.
Disabling elements having a lower value than the minimum support value.

Creation of binary association with considering the created single associations.

Removal of cluster elements that have low value than the minimum support value.

Elements are divided into groups of threes/fours etc. and the same procedure is repeated.

Derivation of association rules after identifying the product group according to support measures.

D. Facility Layout Planning

Aim of facility planning is to determine best plant design by defining related work areas and material locations in facility. It also includes supporting organization task in order to conduct material handling, material controlling and workshop, effective use personnel, material, area and energy, minimizing capital investment, facilitating maintenance to provide flexibility, ensuring work satisfaction and labor safety.

Fig. 2 Facility Layout Planning Hierarchy

Facility layout problem is NP-Hard problem as it has complexity in terms of modelling and calculating [22]. It is related to how facility locates in bounded area. Layout decision problems are called as plant layout problem or facility layout problem in literature. Facility Layout Planning is divided into four groups as p-median, p-center, unbounded capacitated facility layout and quadratic assignment problem [23].

Facility design is coordination with stations’ activities such as handling, storage, quality control etc. with regard to their physical locations. Main target of facility design is to minimize movement of entities related to production activities. The reasons why facility design is necessary are changing in manufacture design and volume of demand, adding a new equipment or good, enlarging or reducing areas, replacing an area, new plan for facility, increasing working accidents, worsening working conditions, minimizing production costs.

III. APPLICATION

In application, Apriori Algorithm was applied to emergency departments’ data by SPSS Clementine with respect to SPSS model which is shown in Fig 3 and confidence coefficient between departments was found.

Fig. 3 SPSS Clementine Model for Apriori Algorithm

Utilizing present facility plan (Fig. 4), rectilinear distance between departments was calculated via Equation 1.

\[ d_{AB} = |X_A - X_B| + |Y_A - Y_B| \]  

(1)

Fig 4: Present Facility Plan

Flow distance values with coefficient were acquired by multiplying flow between departments, distance and coefficients obtained through developed algorithm. Alternative facility layout in Fig. 5 was generated by way of minimizing flow distance values and considering emergency service doctor’s advices such as:

- Patients coming emergency service on foot and by ambulance should enter emergency service from different entrances,
- Patients coming emergency service on foot should not pass red area to head for green district,
- Department of Radiology should be located near red and yellow area,
- A new emergency entrance should be opened for patients coming emergency service on foot.
Compared present and alternative facility layout, we noticed that alternative facility layout is better than other. But this is not optimal solution. It can be improved.

Developed Algorithm Steps;

1. A list is created from relations whose coefficient of reliability was determined by Apriori Algorithm. If there is a single relation whose reliability rate is over %60 or a mutual single relation whose reliability rate is over %50, 7 points are given.

2. Single relations which have 7 points are removed from the list. For the rest, if there is a relation which is single for one side and dual for other side and over %50 coefficient of reliability, 6 points are given.

3. Single relations which have 6 points are removed from the list. For the rest, if there is a relation which is just single for one side and over %50 coefficient of reliability, 5 points are given.

4. Single relations which have 5 points are removed from the list. For the rest, if there is a mutual single relation which is over %40 coefficient of reliability, 4 points are given.

5. Single relations which have 4 points are removed from the list. For the rest, if there is a relation which is single for one side and mutual for reverse side and over %40 coefficient of reliability, 3 points are given.

6. Single relations which have 3 points are removed from the list. For the rest, if there is a relation which is just single for one side and over %40 coefficient of reliability, 2 points are given.

7. If relations are under %40 or there is no any relation, 1 point is given.

IV. CONCLUSIONS

Speed of service is one of the most important indicators for patient coming emergency service. Any delay can be ended with death.

In this study applied in emergency service, flows between the emergency departments (emergency entrance, pediatric emergency department, pediatric emergency observation, radiology, isolation room, minor surgery, resuscitation room, red area, yellow area, green area, plaster room) of patients which come to the emergency departments are examined via SPSS Clementine and confidence rates were found in the relationships between departments. Considering these rates, coefficients were appointed to interdepartmental relationships with the help of algorithm developed. Flow distance values with coefficient were acquired by multiplying flow and distance between departments and coefficient. Alternative facility layout was generated considering emergency service doctor’s advices for minimizing flow distance values taking in consideration patients flow between departments in emergency service; a new facility layout was created.

Multiplying distance and flow was tried to reduce by only decreasing distance. Departments which have the most flow were tried to zoom one another. Multiplying of distance and flow decreased from 83131, 15 to 53385, 7. So, improvement acquired is %36.

REFERENCES


ANT COLONY BASED DYNAMIC NAVIGATION FOR TRABZON CITY

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Abstract—This study contains a simulation of dynamic road navigation system for intelligent transport system. The proposed system uses wireless sensor networks in roadsides. Through a vector map of Trabzon and ant colony algorithm, the optimum route is calculated in vehicles. Wireless sensor networks provide some coefficients such as traffic jams, road length, and average delay time for ant colony algorithm. A small area in Trabzon is considered for the proposed dynamic road navigation. In literature search, it has not found any realistic study that contains intelligent transportation system for Trabzon city.

Keywords—Ant Colony Algorithm, Wireless Sensor Networks, Dynamic Road Navigation, Intelligent Transport System

I. INTRODUCTION

In recent years, there is a growing interest to navigation works. However, many of these works don’t contain actual information about the road or roadside. The proposed method uses Ant Colony Algorithm and coefficients which come from WSN to determine the reliable and short route to the target.

A. WIRELESS SENSOR NETWORKS

Wireless sensor networks (WSN), consist of multiple sensor elements and these networks collect information from the environment in a particular purpose. These sensors usually work autonomously and can adapt to changing environmental conditions. [1]. WSNs are composed of elements called nodes, and the joint work of several units. A sensor node generally contains four main components. These units are: power unit, sensor unit, processing unit and communication unit.

Many studies have been made on routing for WSNs using Ant Colony Algorithm (ACO) [2,3,4]. The majority of these algorithms aim to extend the network lifetime [2]. In this study, it is assumed that there were WSN nodes on the roadsides. And these WSN nodes provide some coefficients such as traffic jams, road length, and average delay time for ant colony algorithm. In this way, the proposed approach can easily find optimum route between two points based on current data in Trabzon city.

B. ANT COLONY ALGORITHM

Ants live in colonies and they make division of labor between them to overcome the difficulties. When an ant finds the food source, the other ants can reach the food source easily by using the most convenient way. The chemical which causes that phenomenon known as pheromone. Ants leave pheromone chemical on the roads which they pass. In addition, they prefer the ways that have much pheromone. Also the pheromone substance has evaporation property. Therefore the amount of pheromone is much more where they frequently pass. Assume that the ants have same speed and they drop pheromone with same rate. Therefore, there will be much pheromone on the shortest path and the ants will prefer that route to go to food source [5,6].

There are two main parameters in the Ant Colony Algorithm. The first one is selection possibility of the route and the second one is evaporation rate of pheromone.
The selection possibility of an ant from r point to s point expressed as follows. [2].

\[ p_k(r,s) = \frac{|T(r,s)|^\alpha C^\beta}{\sum_{u \in M^k} |T(r,s)|^\alpha C^\beta} \]  

(1)

Where \( \alpha > 0, \beta > 0 \) are the effect parameters and take the value as \( \alpha \approx \beta \approx 2 \) typically [7]. \( T(r,s) \) is pheromone matrix and indicates pheromone value related row and column. \( C \) is the cost function and it is thought as multiplication of \( w \) weights come from WSN and path length \( d \).

\[ C = \sum d \ast w \]  

(2)

The pheromone matrix is updated as follows [2].

\[ T_k(r,s) = (1-\rho)T_k(r,s) + \Delta T_k \]  

(3)

In the above equation \( \rho \) indicates that the evaporation rate. In this study, \( \rho \) value was obtained as 0.5.

II. SYSTEM IMPLEMENTATION

A. Using Vector Map of Trabzon for Routing

Firstly the vector map of Trabzon was read in Matlab program and it was selected a particular region for navigation. The satellite image of the selected region shown in Figure 2 below.

Fig. 2 Selected region for navigation work

Random coefficients are assigned to the way parts in this region initially. These weights represent feedbacks that come from Wireless Sensor Networks. Starting point and endpoint coordinates are described to make navigation work.

It is necessary to obtain all possible routes between these points. To make this, it was investigated that how the roads connected to each other.

“extractfield” command was used to extract road coordinates from vector data, so that related x and y coordinates were obtained.

For this purpose the same coordinates were found to find the intersection of two roads. Then the next point was obtained similarly. If there were two or more points which have same coordinates, roulette wheel was used to determine next point.

The coordinates of the path are the sequence shown as figure 3 below. The first row refers x coordinates and the second one refers y coordinates. Column number indicates the index number. As can be seen from the figure, every part of the road separated by "NaN" statement. So the "NaN" statement refers a part of the road.

Fig. 3 The appearance of the extracted coordinates

Different routes to the target were found and then their costs were calculated. Vector map of the selected area with lengths and weights of the paths are given in figure 4.

Fig. 4 Paths lengths and their weights

B. WSN Supported ACA Based Dynamic Navigation

The amount of pheromone will be effective to determine optimum route. Therefore the variations at the pheromone levels are important too. Thus if there are WSN feedbacks such as congestion, rain or slippery surfaces on the road, this will affect the cost function of related path. And some parts of the path will not be preferred in generated route. In this way the dynamic and shorter route that based on actual data will be selected.

The weights are between 0 and 1. The number 1 represents the worst road condition. If the coefficient closer to 0, it indicates that the road condition is fine.
III. CONCLUSIONS

In this study, ACA-based dynamic navigation work was discussed. It is assumed that there were WSN nodes on the roadsides. It is also assumed that these nodes provide some coefficients as feedback. Using these coefficients the cost function was calculated and optimum route was obtained.

Four routes which have minimum costs are shown in figure 5 below. High cost routes aren't shown in figure.

![Fig. 5 Four routes which have minimum costs](image)

Table 1: Routes and their costs

<table>
<thead>
<tr>
<th>Route</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>207.82</td>
</tr>
<tr>
<td>2</td>
<td>286.09</td>
</tr>
<tr>
<td>3</td>
<td>161.56</td>
</tr>
<tr>
<td>4</td>
<td>188.80</td>
</tr>
</tbody>
</table>

Route 3 has the lowest cost as can be seen Table 1. Thus Route 3 will be selected as optimum route. In this study all the roads are assumed to be bidirectional. This topic can be handled in future studies.

REFERENCES

A Robust Hand Pose Correction Method for Palmprint Recognition

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Abstract— The selection of the appropriate pattern for palmprint recognition systems depends on the success of the segmentation techniques used. Segmentation can be difficult due to free movement of the hand in unrestricted environment. Also holding the hand at different angles causes perspective distortions. In order to correct these distortions, active scanning systems have been proposed to find the 3D position of the hand. However, as the cost of these systems is high, it seems that they are not possible to spread.

In this study, a stereo camera system which is more cost effective, have been used. With the help of this system, 3D coordinates of the landmarks falling on hand are calculated. A new transformation is defined based on the main axis of the distribution of these points. Thus perspective distortions are substantially corrected. The success of the proposed approach has been tested on our dataset consisting of hand images taken from 138 people. As a result of the experiments, recognition rate even in the cases reached over 90%.

Keywords— Palmprint Recognition, Stereo Camera, Pose Correction

I. INTRODUCTION

In the first devices developed for palmprint validation [1, 2] cameras which have own lighting system are used. At the time of taking image, a flat surface is used to keep the hand at the same distance. The movement hand is significantly restricted by the pegs in the device. Despite the successful results obtained in these studies, it is mentioned that the pegs cause distress for some users (especially those with physical problems in their fingers) [3-6]. Then unrestricted systems without pegs are proposed. [7-10] However, they are contact systems and cause hygiene problems especially in a multiuser environments [11].

Recent studies about hand biometric systems has focused on unrestricted and contactless techniques that do not need user cooperation. In the unrestricted and contactless systems, in order to overcome alignment problems, hand’s pose and the distance to the camera should be known. It is very difficult to obtain these informations in 2D image. For this reason, some researchers have proposed 3D hand acquisition systems with different characteristics (digital laser scanner [12], structured ligh [13], the depth camera [4], ultrasound [14] etc.). 3D information offered by these systems raise recognition rates as well as presenting some security advantages. However, extra cost of these methods makes difficult to apply them on the palmprint recognition system.

In this study in order to eliminate alignment problems, a stereo camera device which has two webcam is used. Stereo camera systems are more advantageous in terms of cost compared to other 3D techniques. However, the computational complexity of these systems makes it difficult to precise 3D scanning. In the proposed method rather than precise 3D scanning, it has been tried to dermine number of landmarks that may help finding the orientation and location of the hand. Thus, factors affecting the recognition in a negative way emerged in contactless systems (rotation, translation and scaling like) are eliminated to a great extent. After determining hand’s pose in 3D space, perspective correction is performed using geometric transformations. In order to evaluate the performance of the proposed approach, a dataset that contains the stereo images of 138 different people is used. Pose corrections on the images in the dataset are made and necessary patterns for recognition are produced. Hand segmentation on the corrected images and the detection of the palm area (ROI) are made using Active Appearance Method (AAM). Feature vector is produced by Gabor based Kernel Fisher Discriminant Analysis method (Gabor-based KFA). Cosine Mahalanobis (cosmah) distance is used for similarity measure between the vectors.

II. MATERIAL AND METHODS

A. Hand Acquisition Device

An open access dataset of stereo-based palm images was not found in the literature. Therefore, in order to test the proposed approach in this study, a new dataset was created consisting of stereo image pairs. In the device prepared to generate this dataset, two CMOS cameras having the same physical properties were used (Fig. 1). The cameras were placed vertically in the system (up and down cameras). The camera system has its own light source to avoid exposure of ambient light sources. 12 V led strips are used for lighting. The height of the protective box was 25 cm. The distance from the central focus of the two cameras was approximately 3 cm. In the stereo camera system, the internal values and the detection of relative positions of the camera used are required to be gathered the 3D information. Thereby, pre-treatment (camera calibration) is
available in the system. For calibration, 32 chess images consisting of 7x5 squares with edge length of 25 mm are used.

![Fig. 1 Hand Acquisition System](image1)

**B. Dataset**

In the dataset, there were a total of 2760 images (640 x 480 pixels) taken from 138 (47 female and 91 male) individuals based on 10 different scenarios (S1, S2, ..., S10). Images were taken according to previously identified scenarios by giving instructions to the users, but no intervention was made during the making of the images. In six of the specified scenarios (S1, S2, S3, S4, S5 and S10), it has been asked from user to keep their hands parallel to cameras. In the others, it has been asked from users to keep their hands in different directions with an angle of about 30 degrees (S6, S7, S8 and S9).

![Fig. 2 Sample images of a user from the dataset](image2)

**C. Pose Correction**

Perspective distortions arise when the hand is not parallel to the camera plane. Kanganhad et al. [3] apply Iterative Reweighted Least Squares approaches on the point cloud obtained from digital 3D scanner to make pose corrections and have determined the normal vector of the hand plane. 3x3 transformation matrix is defined with the help of this vector. Another approach can be seen in [15]. In this study, the relative coordinates of 7x5 pieces light points directed from light source to the hand is calculated. Projective matrix is created with the help of the normal vector of the plane formed by points. Geometric correction was performed with this transformation matrix. On the correction step of these experiments, rather than finger positions and the distance between hand and the camera, midpoint of the hand is taken as reference and the correction process is made in that position. As the background is monochrome, segmentation is performed without problem.

In our study, first landmarks on each stereo cameras are detected by SURF[16] method. Depth information of these points is obtained with the help of epipolar geometry techniques by matching. Assuming that the hand is the nearest object to the camera plane, all points over a certain distance from the plane have been eliminated. Thus, only point clouds falling on hand was detected.

The pose correction process was conducted according to the distribution of the 3D point cloud detected on the hand. As shown in Fig. 3a, these points are approximately in the form of an ellipse. This ellipse \( \langle \mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3 \rangle \) and its main axis, which are perpendicular to each other, can be found using Principal Component Analysis (PCA). The eigenvector \( \langle \mathbf{e}_1 \rangle \) corresponding to the maximum value detected by PCA is the primary main axis. This axis is in line with the fingers and usually falls on the middle finger. If it is assumed that \( P'_{3D} \) and \( P_{3D} \) are new and current 3D points respectively, then the transformation is represented as:

\[
P'_{3D} = RP_{3D}
\]

where \( R \) is the \( 3 \times 3 \) transformation matrix and is defined as follows:

\[
R = \begin{bmatrix}
\mathbf{e}_1 \\
\mathbf{e}_2 \\
\mathbf{e}_3
\end{bmatrix}
\]

The 3D points detected on the hand and the transformation results of their centralized coordinate values are shown in Fig 3b. It can be seen from the figure that the center of the transformed points is O(0,0,0) and the main axis is along the X, Y and Z axes.

![Fig. 3 (a) The ellipse form of 3D points; (b) original points (black) and transformed points (green)](image3)

In order to apply the proposed transformation to the image, the \( P_{2D} \) constant matrix was created:

\[
P_{2D} = \begin{bmatrix}
y_1 - y_c & y_2 - y_c & \ldots & y_n - y_c \\
x_1 - x_c & x_2 - x_c & \ldots & x_n - x_c \\
0 & 0 & \ldots & 0
\end{bmatrix}
\]

where \( x_i \) and \( y_i \) are image coordinates, \( x_c \) and \( y_c \) are the image’s center points and \( n \) is the number of pixels in the image. In this representation, the image coordinates are assumed as a point cloud along the axis of \( Z = 0 \) in 3D space. The new pose corrected coordinates can be found with the following formula:

\[
P'_{2D} = R P_{2D}
\]

\( P'_{2D} \) represents a transformed new surface in the 3D space and the \( Z \) values are different from 0. \( P_{2D} \) points are transformed to the homogeneous coordinates, and as in equation 5, the perspective projection of the axis \( Z = d \) is obtained.
where \( d \) is the average distance of the points on the hand to the camera plane. The new image coordinates were determined by adding \( x_c \) and \( y_c \) values to \( x_{f_i} \) and \( y_{f_i} \) in the matrix \( P_{2D_r}' \):

\[
x'_{f_i} = x_{f_i} + x_c \quad \text{and} \quad y'_{f_i} = y_{f_i} + y_c
\]

Intensity values corresponding to each coordinate were found by making an interpolation of the values in the original image. With the help of the transformation, the middle finger was arranged along the Y axis in the new image. Thus, the pose of the hand in 3D space was corrected and the fingers in the new image were aligned to face upward (Fig. 4).

![Image 46x448 to 298x517](image1)

![Image 46x528 to 299x595](image2)

![Image 309x237 to 388x317](image3)

![Image 380x523 to 506x637](image4)

![Image 393x237 to 472x317](image5)

![Image 476x238 to 556x317](image6)

![Image 580x972](image7)

**D. Hand Segmentation**

The AAM [17] is based on the philosophy of finding the model parameters that minimize the difference between the target image and the learned average image. Training images previously annotated by an expert are used to create an average image model. Points marked on each image are aligned with Procrustes Analysis and the shape model of the AAM is created. Variations of the shape model are determined by PCA. According to the average shape image, each image in the training set is subjected to a warp process. The texture model is obtained by transforming textures within the delaunay triangulation established between points of the warped image to a vector [18, 19].

\[
s = s_0 - \phi_s p \quad \quad p = \phi_s^T (s - s_0) \tag{7}
\]

\[
g = g_0 - \phi_t q \quad \quad q = \phi_t^T (g - g_0) \tag{8}
\]

where \( s \) and \( g \) are the shape vector and synthesized shape-free texture vector; \( s_0 \) and \( g_0 \) are mean shape and mean texture; \( \phi_s \) and \( \phi_t \) are the eigenvectors of shape and texture; \( p \) and \( q \) are shape and texture parameter vectors, respectively.

It has been recommended that the inverse compositional image alignment approach be the adapted AAM [20]. This algorithm tries to minimize equation 9.

\[
\sum_i [I(W(x; p) - A_0(W(x; \Delta p))]^2
\]

where \( A_0 \) is an average image, \( W(\cdot) \) represents the warping process, \( p \) is the necessary parameter for the warp operations, and \( \Delta p \) shows the parameter change in the next iteration.

In this study, 51 points on 70 randomly selected images in the stereo database are marked for the training of AAM model (Fig. 5). Shape and appearance models of annotated images have been created by training with AAM. AAM points on other images has been tried to be determined using this model. 3 level image pyramid has been created to perform the search process faster.

![Fig. 5 AAM points and ROI](image8)

**E. ROI Extraction**

Detection of the ROI is one of the most important stages of palmprint recognition and affects recognition performance significantly. As AAM-based hand segmentation uses texture information, it provides a significant advantage in the detection of the valley points. In this study, the ROI extraction method used is similar to that proposed by Zhang et al. [1], with an approach allowing a wide area to be selected (Fig. 6c). The valley points required by this method are selected from the control points determined by the AAM. Here, the distance \( d \) between the two valley points was via a proportional relationship. The selected valley points were P15 and P37 (Fig. 5). The ROI was determined to be a square with each side 1.4 d and 0.2 d from the mid-point of the valleys. The obtained ROIs were scaled to 128 \( \times \) 128 pixels.

![Fig. 6 Various RIO extraction methods: (a) Zhang et al. [1]; (b) Connie et al. [11]; (c) proposed method. Skin color segmentation is used in (a) and (b); AAM segmentation is used in (c).](image9)

ROI extraction approach is applied on the image before the pose correction actually the importance of correction emerges clearly. Related results of the same images are shown in Fig. 7.
The Gabor-based KFDA used in the study of Ekinici and Aykut [46] was applied for palmprint feature extraction. In this method, first the frequency and orientation characteristics of the palm pattern are extracted by Gabor wavelets [21]. Then, KFDA is used for transforming low-dimensional feature space in order to distinguish these properties efficiently.

Gabor wavelets inspired by orientation and frequency characteristic of tapered optic nerves of developed live [22] and a filtering technique extensively used in many recognition and representation algorithms. A Gabor function is formulated as (18):

$$g(x,y;\lambda,\theta,\psi,\sigma,y) = \exp\left(-\frac{x'^2 + y'^2}{2\sigma^2}\right)\exp\left(i2\pi \frac{x'}{\lambda} + \psi\right)$$

Where x and y represent coordinates of two dimensional generated matrix. \(\theta\) is Gabor core’s orientation angle, \(\psi\) is the phase angle of the core matrix to be formed, \(\lambda\) is wave length, \(\gamma\) used to calculate standart deviation of y. \(x'\) and \(y'\) is calculated as (19).

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

Kernel Fisher Discriminant (KFD) uses FDA in order to determine non-linear features to distinguish classes in non-linear space. Let us \(\phi\) is a non-linear transformation in \(\mathcal{F}\) feature space. In this case, the objective function of KFA can be written as similar to normal FDA[23]:

$$J(w) = \frac{w^T S_{\mathcal{F}} w}{w^T S_{\mathcal{F}} w}$$

$$S_{\mathcal{F}} = \frac{1}{n_1 + n_2} \sum_{i=1}^{n_1} \sum_{j=1}^{n_2} (\phi(x_i) - m_{\mathcal{F}i})(\phi(x_j) - m_{\mathcal{F}i})^T$$

$$m_{\mathcal{F}i} = \frac{1}{n_{\mathcal{F}i}} \sum_{j=1}^{n_{\mathcal{F}i}} \phi(x_i)$$

In order to formulate the problem in non-linear feature space, it needs to be expressed in the from of inner products of the use of training samples. After implementation of several calculations, the objective function of KFA can be written as follows:

$$J(\alpha) = \frac{\alpha^T K_{\mathcal{F}} \alpha}{\alpha^T K_{\mathcal{F}} \alpha}$$

The solution to this problem is provided by obtaining eigenvalues of \(K_{\mathcal{F}}^{-1} K_{\mathcal{F}}\). The projection of a point \(\mathbf{x}\) to \(\mathbf{w}\) in \(\mathcal{F}\) is given in (31).

$$\mathbf{w}, \mathbf{\phi}(\mathbf{x}) = \sum_{i=1}^{n} \alpha_i k(x_i, \mathbf{x})$$

k is inner product kernel function

$$k(x,y) = \langle \phi(x), \phi(y) \rangle$$

In this study, Gaussian kernel function \((k(x,y) = \exp(-\frac{||x-y||^2}{2\sigma^2}))\) was preferred. To represent the number of class \(\mathcal{C}\), a multi-class structure \(K_{\mathcal{C}}\) and \(K_{\mathcal{B}}\) can be calculated as follows [49].

$$K_{\mathcal{B}} = \frac{1}{C(C-1)} \sum_{i=1}^{c} \sum_{j=1}^{c} (m_i - m_j)(m_i - m_j)^T$$

$$m_i = \frac{1}{n_i} \sum_{j=1}^{n_i} k(x_j, x_j), \ldots, \frac{1}{n_i} \sum_{j=1}^{n_i} k(x_n, x_j)$$

$$K_{\mathcal{C}} = \frac{1}{c} \sum_{j=1}^{c} \sum_{i=1}^{n} (\zeta_i - m_i)(\zeta_i - m_i)^T$$

$$\zeta_i = (k(x_1, x_j), k(x_2, x_j), \ldots, k(x_n, x_j))^T$$

G. Similarity Measurement

The cosine Mahalanobis (cosmah) distance metric [24] was used for the similarity measurement between the feature vectors. To be able to use this metric, first a conversion between feature space and Mahalanobis space is needed. Let us assume that \(\hat{u}\) and \(\hat{u}\) are two vectors to measure the similarity of features in the feature space, and \(\hat{m}\) and \(\hat{n}\) are their conversions in the Mahalanobis space. In this case, \(\hat{m}\) and \(\hat{n}\) are represented as in equations 23-24.

$$\hat{m} = \begin{bmatrix} \hat{u}_1 \\ \vdots \\ \hat{u}_p \end{bmatrix}$$

$$\hat{n} = \begin{bmatrix} \hat{v}_1 \\ \vdots \\ \hat{v}_p \end{bmatrix}$$

where \(\sigma_i\) is standard deviation of the vectors in ith dimension; cosmah is the cosine angle between the vectors after having been projected to the recognition space.

$$D = \cos(\theta_{mn}) = -\frac{\hat{m}^T \hat{n}}{||\hat{m}|| ||\hat{n}||}$$

III. EXPERIMENTAL RESULTS

On the performance evaluations, all comparisons were made by the leave-one-out strategy, and the minimum distance between two feature vectors was regarded as the best match. First, all experiments were performed with the features taken from uncorrected perspective images. Then, the same process was repeated with the features taken from the corrected images, and finally, comparisons of the two were made.

In the evaluation stage of the study, first, the performance of the scenarios parallel to the camera plane (S1, S2 and S3) was measured. The evaluation was made for each camera separately. During the classification process, it was noted that the images
used for training did not match with itself. The cumulative match curves (CMCs) of the first comparisons are shown in Fig. 8, and the verification rates are given in Table 2.

![Fig. 8 CMCs for the unangled scenarios: (a) Up camera; (b) Down camera](image)

TABLE I
RECOGNITION AND VERIFICATION RATES FOR THE UNANGLED SCENARIOS BEFORE AND AFTER TRANSFORMATION

<table>
<thead>
<tr>
<th></th>
<th>untransformed</th>
<th>transformed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Up Camera</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition Rate (%)</td>
<td>99.336</td>
<td>99.457</td>
</tr>
<tr>
<td>EER (%)</td>
<td>0.154</td>
<td>0.127</td>
</tr>
<tr>
<td>FRR (FAR=0.001)</td>
<td>0.242</td>
<td>0.154</td>
</tr>
<tr>
<td><strong>Down Camera</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition Rate (%)</td>
<td>99.336</td>
<td>99.396</td>
</tr>
<tr>
<td>EER (%)</td>
<td>0.095</td>
<td>0.089</td>
</tr>
<tr>
<td>FRR (FAR=0.001)</td>
<td>0.121</td>
<td>0.060</td>
</tr>
</tbody>
</table>

According to the Rank one recognition rate values success of the system on uncorrected images is sufficiently high. However some improvements are achieved on the corrected images.

According to the data in Table 2, the success of the system on the image without corrected perspective was considered satisfactory. Therefore, the rest of the study focused on the performance of the proposed approach on images taken according to the scenario with an angle. In all other evaluations, S1, S2 and S3 images were used for training and the other images were used for testing. The results are given in Table 3 and Fig. 9. All images except the training set were used as the test set (Training set = S1+S2+S3 and Test Set = S4+S5+S6+S7+S8+S9+S10).

![Fig. 9 ROC curve for the angled scenarios before and after transformation](image)

As seen in Table 3 and Fig. 9, the recognition rate on pose corrected images was improved by around 25%, while the EER values decreased significantly. Another important advantage was that the system was also capable of simultaneously producing two patterns of a hand. Two simple fusion models were applied using these two patterns. In these models, images taken from two cameras were used together as a training set. In the first fusion model, if one of the test patterns obtained from the two cameras was more similar to one of the patterns in the training set, it was classified by its label. In the second model a single pattern was obtained by taking the average of the test images taken from the two cameras. Here, in order to evaluate the performance correctly, fusion models were applied on the untransformed and transformed images, and the comparative results are given in Table 5 and Fig. 10. The fusion approaches produced better results than the data in Table 3 in both the transformed and untransformed images. In particular, the Fusion 2 approach applied to the transformed images increased the recognition rate by 3.25% according to the down camera, which had the best value in Table 3. In addition, the EER values decreased from 3.42% to 2.28%.

TABLE II
RECOGNITION AND VERIFICATION RATES FOR THE ANGLED SCENARIOS BEFORE AND AFTER TRANSFORMATION

<table>
<thead>
<tr>
<th></th>
<th>untransformed</th>
<th>transformed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Up Camera</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition Rate (%)</td>
<td>63.35</td>
<td>88.10</td>
</tr>
<tr>
<td>EER (%)</td>
<td>14.82</td>
<td>3.51</td>
</tr>
<tr>
<td>FRR (FAR=0.001)</td>
<td>39.65</td>
<td>12.11</td>
</tr>
<tr>
<td><strong>Down Camera</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition Rate (%)</td>
<td>63.46</td>
<td>89.92</td>
</tr>
<tr>
<td>EER (%)</td>
<td>14.76</td>
<td>3.42</td>
</tr>
<tr>
<td>FRR (FAR=0.001)</td>
<td>38.51</td>
<td>10.56</td>
</tr>
</tbody>
</table>

![Fig. 10 Results of fusion models: (a) ROC curves of fusion models; (b) FAR-FRR graph of Fusion 2](image)
IV. CONCLUSIONS

In this study, the pose information for the palm was obtained from stereo-based hand images in a 3D environment and the images were converted with the help of the proposed geometric transformations. Thus, a pre-processing operation was produced for the powerful 2D recognition techniques. It is evident that the existing 3D systems are more advantageous for feature extraction than 2D. However, the extra cost of these systems and their nonportable devices reduce their applicability.

In this study, 3D information was used only to make geometric corrections with a different perspective because the web cameras, which were used to keep the recognition system’s cost low, were incapable of producing very detailed 3D point information. Detection of depth in high-resolution stereo images does not seem advantageous for real time applications. The most important advantage of this study is that very detailed 3D information is not needed. Also miscalculations of some points because of noise in the images can be tolerated at determination of hand plane equation.

One of the major advantages of the study was that two palm patterns could be produced from two different cameras at the same time used by the proposed simple fusion models to improve the chances of success.

In this study, in order to make the evaluations needed, a stereo-based dataset was compiled using images taken from 138 different people. As a result, the recognition rate ratios of about 62% obtained by each camera evaluated individually were increased to 93.17% by employing a simple stereo fusion approach.

This study revealed the need for perspective correction on the images taken parallel to the camera plane in contactless and unconstrained systems. Although after the evaluations, significant improvements were observed for all scenarios, the obtained results could be further improved upon. In particular, on the high-angle images, pattern distortions can arise, depending on the 3D structure of the hand. Furthermore, some users are unable to completely extend their fingers, in which case, the inner surface of the hand resembles a curved structure. This is one of the factors that negatively affected the success of the system. In the future, studies must further examine the problem of correcting the curves of the palm, and develop techniques to improve the quality of the images.

REFERENCES

Regression Analysis of Fire Doors Resistance and Comparative with Artificial Neural Network Application

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Abstract—Computer and technological developments are positive influences every aspect of life. Parallel to the developments in technology, artificial intelligence applications, mathematical and statistical models, are widely used in many other fields of the industry. Fire chemical is a dynamic event and does spread very quickly if there is no barrier. Today, fire doors are being used as required in all kinds of buildings. Therefore, it’s vital to determine the fire resistance of different doors for different buildings. This determination should be monitored by the experimental studies. In single and multiple regression equations there is a dependent variable which affects a single or multiple independent variables. Artificial Neural Networks (ANN) are intelligent computer software which mimics human brain's neural networks, mainly connected through networks and has the ability to discover, creating and deriving new information by way of learning by making generalizations from samples. In this study experiments were conducted to determine the resistance of the fire door. After the experiments a regression analysis (RA) and an artificial neural network model have been developed by using data obtained from experiments. With this regression model (RM) the internal temperature of the fired room which plays an important role in the resistance of fire, doors have been evaluated. In the proposed system, the temperature values of the thermocouples above the door, Top Left, Top Right, Middle Left, Middle Right, Bottom Left, Bottom Right Temperature (°C) and Time (minute) have been taken as input and In-Room Temperature (°C) as output parameters. The results improved by these two approaches were evaluated in comparison with each other. Regression analysis and the results obtained by the artificial neural network have been compared with experimental data. Accuracy was determined as a percentage. Correlation and determination coefficients were calculated and the fire doors resistance determination ability of models have been compared. It has been observed that the developed model of this kind can be safely used in the determination of the fire door resistance.

Keywords—Regression model, Artificial neural network, Fire doors, In-Room temperature

I. INTRODUCTION

In buildings, fire doors are utilized commonly. These doors entail specific fire resistance and they act as delimiters or fire enclosures. Nevertheless, the thermal and mechanical properties of materials generally change with high temperatures so sufficient knowledge needs to be known about fire behaviors of construction materials of doors to utilize these doors ideally [1]. Structural steel members can be used for the vertical and lateral support in multi-story buildings. These members may be included inside fire-resistant enclosures enabling house elevators, stairs and other services [2].

With the aim of preventing fires spreading, structural failure and enabling evacuation of occupants and intervention by firemen, necessities for fire resistance are given. These are generally expressed for standard fires. This approach that requires classifying products as their fire behaviors is still used in many countries. As compared to the natural fire, thermal actions from conventional fires are symbolic. However, from conventional fires, more severe thermal actions are needed under some conditions [3, 6].

Fire chemical is a dynamic event and does spread very quickly if there is no barrier. Today, fire doors are being used as required in all kinds of buildings. Therefore, it’s vital to determine the fire resistance of different doors for different buildings. This determination should be monitored by the experimental studies. The precautions to be taken to the fire are proportional to recognizing the fire. If the burning and not yet burned but likely possible to be burn materials, fire loads and other conditions are well-defined then the measures to be taken in fire case will be very effective [4, 5].

With the entrance and widely use of computers actively in human life, the usage of biological structure of the artificial intelligence model for the solution of complex problems and increased the use of statistical methods. Referring specifically to engineering research in recent years, there are lots of
different methods like regression models, artificial intelligence-based (ANN, fuzzy logic, support vector machines, etc.) used in different estimates based operations. In this study the ANN and RM which are the most widely used methods have been used.

In this study, at first an experimental study has been carried out to determine the fire resistance of fire doors. Thermocouples were placed at the surface of door and were connected to data logger to record the data. System was modeled by an artificial neural network with 7 inputs and 1 output which is an artificial intelligence techniques and RM using non-linear experimental data and fire room interior temperature values were estimated. These two models were compared with each other and the model that give the closest result to experiments have been identified.

II. EXPERIMENTAL SETUP

In the study, a test mechanism was prepared for one fire and smoke control doors used as fire doors according to the rules of TS EN 1634-1 and an experimental study was carried out. At the same time, digital thermometers (thermocouples), thermal camera, fire door, gas concrete wall and inflammable wooden materials are used materials [7].

The experimental study was carried out at the laboratory of Construction Department of Selcuk University Higher School of Vocational and Technical Sciences. The experiment images from fire door and mechanism and is given in Fig. 1.

After the experimental mechanism was prepared, all the indicators and devices were tested in terms of working and first fire was lit. Since the beginning of the fire, all data records were beginning to be recorded. Experiment time continued for 136 minutes and during this experiment all data were recorded. For each one minute, data were recorded to data logger from 6 thermocouples and at the end of the experiment these data were transferred to computer [8].

III. ANN MODELING

Artificial Neural Network can be defined as a mathematical model that tries to mimic the human brain cells.

There are many advantageous aspects of ANN such as being able to do parallel processing, ability to learn, making generalizations and ease of analysis and design. One of the most important features is that different information can be derived without requiring help from the new knowledge acquired through learning.

In this study, for the predict the in-room temperature (°C), an ANN structure with 7 inputs and 1 output was designed and application was performed using the designed structure (Fig. 2). As input parameters, Top Left, Top Right, Middle Left, Middle Right, Bottom Left, Bottom Right Temperature (°C) and Time (minute), as output parameter In-room Temperature (°C) were taken. The performance of the ANN was presented by examining the consistency between the values obtained through the ANN approach and the experimental data [10].

![Fig. 2 Structure of ANN model for this study](image)

Feed-forward back-propagation algorithm was used in feed forward single hidden layers. It was aimed to find the most appropriate network model by changing certain parameters such as the number of hidden layers, the number of neurons used in hidden layers, epoch number, training functions and transfer functions. The data sets selected for training and testing were trained using Levenberg-Marquardt (trainlm) algorithm respectively and the results were obtained. Training algorithm and activation functions were tested using the software developed and results were obtained in the matlab program.

IV. REGRESSION ANALYSIS

One of the most widely used area of utilization of the statistical studies is regression analysis. In case there are more than one factor affecting a case, researching of cause-effect relation becomes possible with regression analysis. A regression model consists of dependent and independent variables. Independent variable is the variable which is not coincidental and used to express dependent variable.
Generally, multiple regression analysis is used to find mean output values relating to dependent variable \( y_9, 11 \).

Functional form of simple linear regression model can be written in the form of equation (1) for a mass \([9]\).

\[ Y = \beta_0 + \beta_1 X + \varepsilon \]  
(1)

In this model;
- \( Y \): Value of dependent variable,
- \( X \): Value of independent variable,
- \( \beta_0 \): Sectional of \( Y \) for mass (constant term),
- \( \beta_1 \): Slope of mass regression line,
- \( \varepsilon \): Error term

In this study, modelling approach is developed with ANN by utilizing the data obtained experimentally \([10]\). Using statistical analysis of the same data, the system of single and multiple regression equations was created with the SPSS program. Temperature values were found with the estimation of in-room temperatures (°C), by using the mathematical expressions obtained with RM. RM results were compared separately with the values obtained by both the experiments and ANN model.

The descriptive statistics 136 values for the in-room temperature can be seen in Table I.

### Table I

<table>
<thead>
<tr>
<th></th>
<th>range</th>
<th>minimum</th>
<th>maximum</th>
<th>mean</th>
<th>std. error of mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (minute)</td>
<td>136.0</td>
<td>1.0</td>
<td>136.0</td>
<td>69.03</td>
<td>3.42</td>
</tr>
<tr>
<td>Top Left (°C)</td>
<td>284.1</td>
<td>3.2</td>
<td>387.3</td>
<td>163.72</td>
<td>9.13</td>
</tr>
<tr>
<td>Top Right (°C)</td>
<td>335.5</td>
<td>3.0</td>
<td>338.5</td>
<td>186.78</td>
<td>10.27</td>
</tr>
<tr>
<td>Middle Left (°C)</td>
<td>353.5</td>
<td>4.1</td>
<td>357.7</td>
<td>208.36</td>
<td>11.16</td>
</tr>
<tr>
<td>Middle Right (°C)</td>
<td>330.3</td>
<td>3.4</td>
<td>333.7</td>
<td>184.76</td>
<td>10.37</td>
</tr>
<tr>
<td>Bottom Left (°C)</td>
<td>275.1</td>
<td>3.6</td>
<td>278.7</td>
<td>134.71</td>
<td>9.12</td>
</tr>
<tr>
<td>Bottom Right (°C)</td>
<td>220.7</td>
<td>3.3</td>
<td>224.0</td>
<td>122.45</td>
<td>7.21</td>
</tr>
<tr>
<td>In-Room Temperature (°C)</td>
<td>944.0</td>
<td>17.0</td>
<td>961.0</td>
<td>720.09</td>
<td>25.70</td>
</tr>
</tbody>
</table>

RM models and temperature (°C) determines dependent variable In-Room Temperature (°C) and independent’s variables affecting this situation, Top Left, Top, Right, Middle Left, Middle Right, Bottom Left, Bottom Right Temperatures (°C) and Time (minute) based on regression equations were generated using seven parameters. The regression equations generated by the SPSS software, the status of each variable were calculated correlation coefficients obtained and determination.

The highest correlation (R=0.986) is obtained by linear multiple regression equation by using these seven variables. And, the closest results to the experiment are obtained in this way. In addition, when in-room temperature (°C) is predicted with multiple regression equation, determination coefficient is found as \( R^2=0.973 \) (Table II-model summary). The best result in the regression models is seen in Table III. It suggests that the values are meaning and compatible statistically. According to correlation values found, it is seen in the \( r \) column in Table II that there is a general strong relation in the same direction between in-room temperature (°C)’s calculated with RM and in-room temperature (°C) measured in the experiment (Table III).

### Table II

<table>
<thead>
<tr>
<th>Change Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>R (r) R Square Adjusted R Square Std. Error of the Estimate R Square Change F Change df1 df2 Sig. F Change</td>
</tr>
<tr>
<td>.986 .973 .971 50.44414 .973 662.540 7 129 .000</td>
</tr>
</tbody>
</table>
V. RESULTS AND DISCUSSIONS

This study is the determination and testing process of the fire resistance of the fire door which would be used in a fire that may be encountered in all living spaces. A model has been established that can determine the fire resistance value of the fire door in line with the regulations. The study emerges as the application of two different methods. First method is the ANN model using data generated in experimental studies. The second study is the formation of RM phase by using the same data again. The results obtained by these two methods were compared with the experimental data and attempts to determine the best model has been made.

As a result of ANN modelling:
In the single hidden layer network structure, number of neurons in the hidden layer values respectively and epoch number were used for all training and testing algorithms and the results were observed. What is more, considering the smallest values in Mean Square Errors (MSE) and the biggest values in $R^2$, their averages were calculated. Then, the best models were found according to this. Among all the circumstances, the trainlm training algorithm and logsis transfer function gave the best result. Also the (7-14-1 (50 epochs)) model was used, which had the lowest MSE error values and the highest $R^2$ values. The graphs that show the comparative results are presented below. The developed ANN system (training) results and the real measured values were evaluated. The graph shown in Fig. 3 indicates that the correlation coefficient was 0.99992 which indicates a perfect match between ANN estimation values and real data [9].

![Fig. 3. The relationship between experimental and ANN prediction values](image)

When temperature is estimated with RM approach which is used as the second resolution method, it has been shown that the effective results can be obtained. In the estimation process with RM, when values obtained at the end of the studies using linear regression analysis (Equation 2) compared with the experimental data, it was observed to be considerably proximate. Correlation analysis between the RM experiment values (Figure 4) yielded $R$ as 0.986. Correlation results of the two groups of data from the experiment and the model, shows that the results are interrelated and the consistency between data can be seen.

### Table III

<table>
<thead>
<tr>
<th>Estimation Equation</th>
<th>Unstandardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>in-room temperature ($°C$) $y$</td>
<td>Regression Coefficients</td>
</tr>
<tr>
<td>Constant-$a_0$</td>
<td>24.168***</td>
</tr>
<tr>
<td>Time (minute)-$b_1$</td>
<td>9.699***</td>
</tr>
<tr>
<td>Top Left ($°C$)-$b_2$</td>
<td>12.620***</td>
</tr>
<tr>
<td>Top Right ($°C$)-$b_3$</td>
<td>-2.687***</td>
</tr>
<tr>
<td>Middle Left ($°C$)-$b_4$</td>
<td>-3.057***</td>
</tr>
<tr>
<td>Middle Right ($°C$)-$b_5$</td>
<td>2.664***</td>
</tr>
<tr>
<td>Bottom Left ($°C$)-$b_6$</td>
<td>-8.839***</td>
</tr>
<tr>
<td>Bottom Right ($°C$)-$b_7$</td>
<td>-1.652***</td>
</tr>
</tbody>
</table>

*** P<0.001 ns not significant (P>0.05)

Linear multiple regression equation obtained in this way is expressed and the system is guessed (equation 2).

$$y=24.168+(b_1*9.699)+(b_2*12.620)+(b_3*(-2.687))+(b_4*(-3.057))+(b_5*2.664)+(b_6*(-8.839))+(b_7*(-1.652))$$

(2)
In this study, regression analysis which is a statistical approach and artificial neural network approach has been performed separately using data from experimental work and two different methods have been established to predict in-room temperature (°C). The data obtained from the developed model with experimental data has been compared statistically, it is seen that the designed model gives successful outcome. When the analysis was assessed, the in-room temperature obtained from the ANN was very close to the experimental results. It has been observed that the developed models of this kind can be safely used in the determination of the fire door resistance. In the subsequent studies, the workspace can be expanded by adding more number of parameters and using different models.

VI. REFERENCES

Mobile Accident Notification

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Abstract—Traffic accidents are one of the most important and serious problems, our country encounters. As the percentage of injured and casualties in traffic accidents are huge in numbers, it causes thousands of people injured or dead in a year. In the situation of coming by a traffic accident that we face commonly in daily life, generally people directly use their mobile phones and call the related units. However, as the required, right and adequate information is not given to these related units, the cases may sometimes end with casualties. One of the most important reasons of casualties in car accidents is the wrong, senseless first aids performed to the victims of injuries by surrenders. In this study, the aim is to determine the exact location of the accident with its latitude and longitude that is determined automatically via the application present in the responsive citizen who tries to help the victims of the accident.

With this system named as “Mobile Accident Notification” the users are aimed to send accident notification in online or via sending message when there is no internet access with the help of mobile applications that process in Android Operating System. These accident data kept in remote server are monitored on web pages or Android mobile phones. In this thesis, a web-based, open-source accident filtration system was developed and the accidents were provided to be monitored by the authorized people in related units.

Keywords—Mobile accident, Accident notification, Mobile accident tracking, Android mobile accident statement

Preventing traffic accidents is a shared concern of the whole world. Since the ratio of deaths and injuries significantly high, thousands of people die and hundreds of thousands of people get injured in considerably high number of accidents in each year. When an accident occurs in daily life, the common practice is to call relevant units and institutions. However, since sometimes correct information is not given to relevant units, many lives are lost. Minutes after the accident occurs (the time from the injury until the hospital care) are crucial for resuscitating accident victims and reducing physical effects of the accident. Improving first aid services is anticipated to reduce casualties up to 20% [1]. Among the reasons of injuries in traffic accidents resulting in casualties and permanent disabilities are late arriving ambulances and series of unapprised interventions of bystanders to accident victims. When reasons of late arrivals of ambulances are examined, various causes listed below are observed [2].

- Distance of the accident scene to the location of ambulances
- Ambulances receiving wrong directions
- Ambulance drivers not being able to locate accidents due to lack of knowledge of exact latitudes and longitudes of accidents.
- Directing ambulances to false locations (pranks etc.)
- Deploying un-operational ambulances from faraway centers to the accident scene, rather than nearest ones, due to lack of communication
- Inadequate number of ambulances when the accident occurred
- Traffic jams
- Ambulances not being able to pull up close to accident scenes due to irregularly parked cars on streets and avenues.

The objective of this thesis is to avail responsive citizens to notify accidents with an application downloaded into their personal mobile phones and to directly locate the scene of the accident on the map by automatically retrieving latitude and longitude values of the informant. Additionally, by filling a form included with the application, appropriate number of ambulances and police will be diverted to the accident scene since the exact number of people injured will be learned or possibly life saving information will be given to healthcare professionals since the nature of the injuries will be identified. Further objectives of this thesis are grouped under general headlines below.

ACCIDENT NOTIFICATION AND DETECTION SYSTEMS

Accident notification systems are usually the process of calling the phone numbers of related units and informing about an accident. With this notification method generally people either call the police and request other units to be dispatched or call the emergency services to request an ambulance to be sent to the scene of the accident.

In case of accident detection systems, usually the detection is realized by reading the data from sensors attached to
vehicles. Another method is a study conducted by Amin et al.[3] where data from GPSs of smart phones are read in 0.1 second intervals and the location of the vehicle is located by map matching algorithms and then the previous speed values collected in 0.1 second intervals are subtracted from the subsequent speed values where the difference is then compared to the threshold values to determine if an accident occurred or not. Additionally there are other solutions such as detecting accidents without interaction with Electronic Control Units, false positive preventions and WreckWatch client-server architecture. One final distinctive study is done by placing noise and image recording cameras on junctions and start recording exactly when the accident occurs by recognizing the noises from the cars involved in an accident and by not recording continuously but only when the accident took place [4].

User prefers this method if there is internet connection and when he/she does not want to enter too much information. When the user clicks on fast notification (GPS must be active), a record of the accident is created in the database immediately. The other information on the form is updated with the data entered by the user. Since the location of the accident and the location where the user filled the form may significantly differ, a record is immediately created when fast notification is clicked. For that reason the record is created immediately after the user clicked on the fast notification; other information can be updated at a later time.

- Detailed Notification

The user prefers this method if there is internet connection and if he/she is willing to give detailed information such as a photograph of the accident scene, license plates of vehicles, number of vehicles involved, estimated distance of the accident, etc. When the user clicks to the detailed notification (GPS must be active), a record of the accident is created on the system database. Other information is updated by the user entering appropriate data. When detailed notification is clicked, the notification is generated. The reason for creating an immediate record is explained in Fast Notification section.

FILTERING NOTIFICATIONS

When an accident occurs, many notifications are sent by users. However since these notifications are for the same accident, they have to be filtered and recorded under one singular accident. For that purpose several constraints should be defined. These constraints can be listed as follows;

- Diameter

Indicates the required diameter for notifications sent by different users to be perceived as belonging to the same accident. It is a parameter used to add all informants under the same category.

- Estimated distance

This is a criteria put forth to receive data from the nearest point to the accident among many
different notifications by taking the estimated distance of the informant to the accident scene.

SENDING RELATED ACCIDENT MESSAGE TO RELEVANT UNIT WORKERS

This is the process of sending messages according to the notifications of various informants to the closest Police Headquarters, Health Institutions and Fire Department workers.

M- ACCIDENT NOTIFICATION APPLICATION

With this application; it is targeted to create awareness among end-users by involving latest technologies to intervene accidents in a timely manner. This study came forth with the idea of ensuring fast and productive interference to accidents and with minimizing the response period during when accidents occur until first aid services reached to victims, is developed by using many integrated web and mobile technologies altogether.

In the thesis, two of them mobile, one of them web based, three different applications are developed. A single database is used for every each application. The application is consisted of three modules. These are; SMS Filtering module, Notification Sending module and administrator follow-up module. Detailed explanations and screen shots from these modules will be given in the upcoming sections.

CONCLUSION

One of the major concerns of our country as well as the world is traffic accidents. In the name of preventing these accidents which result in hundreds of thousands of casualties each year and cause many of them left with permanent disabilities, science people and researches have conducted many widespread studies. In the light of these studies, they have proposed several accident detection and accident tracking systems underlying how these accidents can be prevented. In one of those studies, a three-step protection method has been offered by Kraus et al[5]. The first of these protection methods is the detection of causes of accidents and taking necessary protections against them; the second method is things that need to be done when an accident occurs and measures that need to be taken to reduce severe effects of accidents; and the final method is what needs to be done after accidents occur and necessary precautions to minimize effects of injuries[5].

Taking inspiration from what needs to be done when an accident occurs, as pointed out in the second method of the study by Kraus et al above, and many other similar studies, actions to be taken in order to minimize the time from the moment the accident occurs until the first intervention to the accident victim (the golden hour) and to treat accident victims in the shortest possible time with the help of the support of a mobile application has been tried to be conveyed in this thesis. With this study, automatically obtaining latitudes and longitudes of exact locations of user/users who have witnessed the accident through GPS, either via the internet connection or when there are no internet connections, via SMS text messaging method has been achieved. With numbers of people injured as well as other pertinent data entered in the form, dispatching both adequate number of ambulances and diverting relevant police units to the accident scene have been targeted. Depending on the nature of injuries, determining and transferring probably life saving information to healthcare professionals has been proposed. At the present time when an accident occurs, among reasons of late arrivals of relevant units to the accident scene are; receiving wrong directions or not being able to find the correct address. With this application, actions such as; direct determination of the exact location of the accident on the map by taking the information of the closets users was targeted. In summary, with this thesis actions such as; contacting emergency services of nearest hospitals, contacting nearest Police Headquarters, totally eliminating the risk of giving wrong directions to ambulances, dispatching ambulances to the correct location by extracting exact latitudes and longitudes of accident scenes on the map, by collecting data from the informant such as his/her exact latitude and longitude, number of vehicles involved, number of injured, and the nature of injuries, dispatching adequate number of ambulances with appropriate equipment, when tens, sometimes hundreds of people inform an accident, giving only the notification of the relevant accident will be taken. When this mobile application is used, it is our belief that the time passed from the moment the accident occurs until the first intervention to accident victims will be minimized, adequate number of equipment and vehicles will be dispatched to the accident scene, assistance will arrive on the shortest time possible by utilizing maps, closest relevant units will be dispatched to the location and many similar advantages will be provided. No such study has been conducted ever before. Therefore a study like this is believed to immensely contribute to the literature as well.

REFERENCES

Real Time Blood Type Determination by Gel Test Method on an Embedded System

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Abstract— Determination of a blood type has a crucial importance for blood transfusion. Therefore it is mandatory doing tests to determine blood type before the transfusion. In order to prevent the errors in determining blood type and to save time these tests are carried out by the automatic devices. However these devices are very expensive and it is necessary to develop cheaper alternative systems. In this study, we designed a basic device which will be a first step for a cheap and fast prototype. It utilizes the image processing techniques and gel test method for real time blood type determination on embedded system. During the tests, fifty gel test cards data were used and, it is found that the proposed system can process each gel test card in 2 seconds with 99% accuracy on average.

Keywords— Image Processing, Blood Types, Embedded Systems, OpenCv, Gel Test Method

I. INTRODUCTION

Determination of blood type is a vital process before the blood transfusion. Otherwise fatal consequences may occur.

It must mandatory doing blood type determination tests to avoid this situation. International Society of Blood Transfusion (ISBT) had recognized a total number of 30 human blood group systems, with ABO and Rh as the two most common groups [1]. The most important blood group is the ABO group. The ABO group system has A, B, AB and O blood types. Type A, B and AB have A, B and AB antigens respectively on the surface of the red blood cells (RBCs), whereas type O has none of these antigens [2]. The second most significant blood-group system is the Rh system. The Rh system determines blood type from the presence or absence of a “Rhesus factor” surface on red blood cells. If Rh factor is present on surface of the RBC it is positive otherwise it is called negative. According to the ABO and Rh grouping systems there are 8 blood groups. These are A Rh+, A Rh-, B Rh+, B Rh-, AB Rh+, AB Rh-, O Rh+, O Rh-. A, B, D (Rh) antigens tests are carried out for determination of blood type [3].

Until recently different methods have been developed to determine the blood group types. Most of the techniques applied today are based on the principle of interaction between antigen and antibody. As a result of this interaction, results are interpreted as positive if agglutination of RBCs occurs and negative if otherwise. The first method used for determination of blood type is called Slide method in which three blood drops are dripped on separate lams then A, B, D antigens are dripped respectively on lams and blood type is determined by angulation [3].

In this study gel test method is used for determination of blood type which is widely used in Tukey. The gel card used in this method is shown in Fig 1. Gel card has a special gel and blood cells which don’t agglutinate passes through this gel and accumulate at the bottom of the tuple [4].

Looking at literature there are several studies for determination of blood type. Zarifi and co-workers used plate method for detection of blood type on FPGA [5]. Feraz developed a prototype system for emergency situations and used slide method in this system [6]. Fatima determined blood type using slide method microscope images by using image processing techniques [7]. Dolmashk and colleagues using laser light radiation and image processing techniques together have shown that the detection of blood group is possible [8]. Swarp and colleagues compared conventional tube method and gel test method [9]. Toz and colleagues developed a software for reading gel test cards by using image processing techniques [10]. Also there are several devices for blood type determination. Some of them are Technicon Auto Analyzer [11-13], Auto-Grouper [12], Technicon Auto Analyzer II [14,15].

Gel test method needs three devices. These are gel test centrifuge, gel test incubator and gel test reader. These devices are very expensive. In general, technicians in hospitals are detecting blood type visually instead of gel test reader. Therefore errors in reading or interpreting cause hundreds of fatal blood transfusions over a year. Furthermore, analysing a large number of samples consumes a lot of time and requires special care for the sampler. In this study, our aim is to develop a cheap, fast and efficient system for gel test reader device. For this purpose a system is designed on Beagle Bone Black (BBB) which is a mini computer card which can run Linux operating systems. It is useful, stronger and cheaper alternative for image processing applications. Using an USB web cam gel card images were taken and image processing techniques are applied on BBB for detection of blood type.
II. MATERIALS AND METHODS

Designed system is consist of BBB and an USB camera connected to it, a fix background and a moving belt.

A. Gel card test method

Gel card used for gel testing method is manufactured by company DiaPro. Fig 1 shows an example of gel card. The size of gel card is 5x35 cm and it has 8 tubes in total but first 5 tuples are necessary for detection. Fig 5 shows the required area for detection. Every tube has a special gel which allows the passage to the bottom of the tube for non-agglutinated blood cells. If blood cells don’t agglutinate they move to bottom of the tube. This situation reveals a negative result (Fig 2). 25 ul of blood was added drop wise into each tube and centrifugation was performed for the detection of blood group. After this process gel card image is taken. Fig 4 shows a B Rh + gel card, ready for determination of blood type.

B. Image processing techniques and Embedded System

OpenCv library and python programming language is used for image processing techniques. On the hardware side BBB minicomputer card and an USB web cam is used. USB can take 640x480 resolution image. BBB has Angstrom Linux operating system. The system has been tested in closed environment and constant intensity of light used to stop the effects of external factors. In this way, the problems of intensity of light and light angle have been removed.

III. RESULTS

Fig 3 shows image processing algorithms used in this study.

1) Detection of motion in System: Static background motion detection algorithm is used for detection of motion in the system. This algorithm is based on substruction of static background image taken at the (t-1) time from the image taken at (t) time principle. A threshold value is set and after subtraction every pixel is compared with this threshold (Th) value. If pixel value is bigger than threshold value it is counted by counter. When the counter value reached to a predetermined value (Th2) motion is detected. The formulization of this process is given below.

\[ |I_t(x) - I_{t-1}(x)| > Th \Rightarrow c = c+1 \text{ and if } c > Th2 \text{ motion is detected.} \]

2) Conversion of grey level image: Fig 4 shows an example of a gel card image taken after motion detection. RGB (Red, Green, Blue) image was converted grey image by using
formula given below. Fig 5 shows grey level gel card image example.

\[ Y = 0.299R + 0.587G + 0.114B \]

![Figure 4. BRH + gel card example](image)

**Figure 4. BRH + gel card example**

**Figure 5. Grey level gel card**

3) Detection of ROI (Region of Interests) and conversion binary image: In this process ROI area was cropped from the grey level image for detection of blood type. In this system since each gel card has a static location in front of the camera, ROI was obtained by cropping the gel card image from specified points. In order to obtain binary image, the adaptive threshold algorithm was applied on ROI

![Figure 6. Cropping ROI area](image)

**Figure 6. Cropping ROI area**

4) Edge detection and Dilation: After the binary conversion the Canny algorithm was applied for edge detection. Furthermore to enhance the image dilation operation was performed. Fig 8 and Fig 9 shows results respectively.

![Figure 7. Binary image](image)

**Figure 7. Binary image**

![Figure 8. Edge detection](image)

**Figure 8. Edge detection**

![Figure 9. Dilation](image)

**Figure 9. Dilation**

5) Cropping ROI areas for detection: A, B, AB, RH1, RH2 ROI areas was cropped from the image for determination of blood type. First white areas was detected and then this areas was cropped from the image. FindCounters function in OpenCv library was utilized for this purpose. Fig 10 shows results respectively.

After cropping operation y coordinates of white areas was detected and compared with each other. According to this comparison blood type is determined and saved in a txt file in BBB. After saving blood type, the system is ready for another gel card. All process explained above is taken 2
second. This time is very efficient value for a real time system [5].

![Figure 10. Cropped gel card tubes](image)

IV. CONCLUSIONS AND DISCUSSIONS

The Blood type determination test is one of the most important test performed in hospitals, blood banks, and other health organizations. Gel test method is one of the blood type determination methods which is widely used in Turkey. In this study our aim is to develop a cheaper and efficient alternative system for blood type determination. During the tests, fifty gel test cards data were used and, it is found that the proposed system can process each gel test card in 2 seconds with 99% accuracy on average.

REFERENCES


Modeling of Compressive Strength of Different Sizes Wood Materials by Regression Analysis

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Abstract— Timber is used widely in construction industry lately due to its some advantages such as neutrality, lightness, environmentally-friendly, resistant against earthquakes, manufacturing flexibility, and having a good compatibility with other construction materials like steel, concrete, and adobe-like materials. Fire retardant materials are used in order to protect wood from the fire. The main task of the fire retardant material is to protect timber against fire, besides it is very important to know whether the retardant material has any effect on the compressive strength of the material or not and it would help the designer to make a choice based on material sections. Today computer technology is widely used in the construction industry as well as in all sectors. Various mathematical and statistical methods are used for computer-aided models. In this study samples with different dimensions and different fire-retardant materials has been prepared from most commonly used wood materials in the construction sector. The compressive strength test has been applied on the samples after certain operations. The data obtained from experiments have been used to apply regression analysis (RA) which is a statistical approach and regression models (RM) have been established to predict compressive strength (CS). Data like wood sample weight, cross-section, volume and breaking load were used to create regression equations for estimating the tension. The data obtained from the regression model developed by experimental data were statistically compared, it is seen that the outcome of the designed model is successful. When the correlation coefficient between predicted compressive strength values and generated models was calculated, it has been seen that the methods applied can be used safely. The data obtained from regression models is close to experimental data and such models can be used to estimate the compressive strength wood.

Keywords— Regression analysis, Species of wood, Resistance of wood against pressure

I. INTRODUCTION

Since ancient times, trees and timber have been used as construction materials. In that sense, the importance and preservation of the forests is crucial. The fact that wood can be used in different fields of life, is closely related to strength of timber-type materials in the field where it is used. Therefore, it is important to determine the applicability of timber, namely mechanical properties of it should be determined. In design stage, it is very crucial to determine the physical and mechanical properties of the materials used in structures. In addition, the safety of element composed from timber are determined by whether it is strong enough to withstand against internal stresses which occurs as a result of external forces [1-2].

Because of the many advantages of timber such as strength and versatile ease of use, it has been widely used as a construction material for many years from the past till today [3]. Timber is a natural material which is used in today’s construction sector and it has been widely used in the past and will continue to be used. Moreover, timber can be renewed in terms of planting new one and can be accepted as a non-consumable resource [4]. The properties like naturalness & temperature, lightness, being an eco-friendly and, earthquake resistant material, providing manufacturing flexibility, compliance with other construction materials such as steel, concrete and adobe, aesthetical and acoustic properties have a huge role in the preference of timber, in spite of increasing acceleration in technological developments in the construction sector in recent years [5]. Historical structures where wooden material usage providing good examples in many fields, can be encountered in both our country and many other countries. Because necessary measures weren’t/aren’t taken in the past/future when wooden material is used, lots of wooden structures catch on fire they are completely destroyed or substantially damaged [6].

With the aim of protecting wooden materials from fire, fire retardant polishes, boron-based impregnated materials, fire retardant paints, etc. are used. An experimental study was performed about whether coating materials which are fire retardant at specific rates, decrease the strength of wooden material or not. 3 different dimensions used with different aims in construction affairs, 3 different types of wood which is easily supplied in our country and 2 different coating materials which are widely used and a raw material which is coated as proof bar are used in experimental study [7-8].

In engineering studies, statistical approaches, regression analysis, mathematical modelling, fuzzy-set-based technical, artificial neural nets and artificial intelligence approaches etc. can be widely used to estimate one or more than one parameter and for different modellings. Regression analysis is a linear or
non-linear statistical field, where it is used with the aim of being able to determine the cause-effect relation between two or more variables that can be used to estimate or approximate about that subject. Therefore, one of the most suitable methods of the process of determining wooden compressive strength is to use regression model. In this process, the fact that parameters can be included in statistical model positively affects the accuracy of result [9].

In this study, samples are prepared at different dimensions and with different fire retardant from different types of wooden materials which are widely used in the sector of construction. Tension stress tests are applied to these samples after specific processes. Regression analyses (RA), which are a statistical approach by using data in these experimental studies, are made and regression models (REM), which can estimate compressive strength (CS), are composed. Results are compared considering coherence between REM and experimental results.

II. EXPERIMENTAL STUDY

For the experimental studies, primarily, the types of fire retardant materials which are most frequently available in the markets were analysed. For wood, an imported fire retardant which are in conformity with UNI EN ISO 14001: 2004 (ISO 14001: 2004) [10] standards and boron impregnated material in conformity with (ISO 14001, 2004) standards were preferred.

Three types of wood were chosen to use in the experimental studies. One of them is Scotch Pine (Pinus silvestris L.) with the density of 620-780 kg/m³ frequently preferred in the buildings, the other is fir tree (Abies sp.) which has the density of 430-520 kg/m³ and poplar tree (Populus sp.) with the density of 310-400 kg/m³ were preferred.

For pressure tests, a computerized full automatic testing device with the capacity of 200 tons (2000 kN) which was produced by Ankara originated Yüksel Kaya Machinery in accordance with the standards of ISO9001(2000) Quality Management System and Press 5.4 version prepared by the company and the experiments were conducted. The pressing machine and computer program which the experiments were conducted are seen in Fig. 1.

The prepared wooden samples were located cantering the pressing machine a gradually increasing pressure stress (0.3 - N/s) was applied from bottom and top surfaces until the samples were broken. The pressure values applied to the wooden samples were automatically given by the computer program. In the experiment, the averages of each 3 samples were taken and the 27 results were obtained [8].

III. REGRESSION ANALYSIS

One of the most widely used area of utilization of the statistical studies is regression analysis. In case there are more than one factor affecting a case, researching of cause-effect relation becomes possible with regression analysis. A regression model model consists of dependent and independent variables. Independent variable is the variable which is not coincidental and used to express dependent variable. Generally, multiple regression analysis is used to find mean output values relating to dependent variable [9].

Functional form of simple linear regression model can be written in the form of equation (1) for a mass [11].

\[
Y = \beta_0 + \beta_1X + \varepsilon
\]

In this model;
- \(Y\): Value of dependent variable,
- \(X\): Value of independent variable,
- \(\beta_0\): Sectional of \(Y\) for mass (constant term),
- \(\beta_1\): Slope of mass regression line,
- \(\varepsilon\): Error term

For it, the specifications of wood materials are created with single and multiple regression equations of the system with SPSS program by statistical analysis method by taking advantage of data obtained experimentally [8]. The values of compressive strength (CS) are found and compared to experimental results by estimation Tension (kgf/cm2) with mathematical notation obtained with RM. The descriptive statistics 27 values for compressive strength can be seen in Table I.

In this study, regression equations are composed using these four parameters by getting dependent variable Tension (Tn-kgf/cm²) which determines compressive strength and independent variables, Test Material Weight (TMW-gr), Material Cross-Section (MCS-mm²), Material Volume (MV-mm³) and Breaking Load (BL-kgf) which affect this situation. With the regression equations composed in the software SPSS, the situation of each of the variables is calculated with correlation and determination coefficients obtained.

The best result in the regression models is seen in Table II. The highest correlation (R=0.926) is obtained by linear multiple regression equation by using these four variables. And, the closest results to the experiment are obtained in this way. In addition, when Tn is guessed with multiple regression equation, determination coefficient is found as (R²=0.858). It suggests that the values are meaning and compatible statistically. According to correlation values found, it is seen in the r column in Table II that there is a general strong relation in the same direction between Tn’s calculated with RM and Tn measured in the experiment.

Linear multiple regression equation obtained in this way is expressed and the system is guessed (equation 2).

\[
Tn = 401.929 + (0.017 \times TMW) + (0 \times MCS) + (-0.0000936983624273154 \times MV) + (0.006 \times BL) \tag{2}
\]

Mathematical formula can be created without a need for MCS variable in RM developed like Table II.
IV. RESULTS AND CONCLUSION

It is seen that Tn is estimated with the RM approach and effective results can be acquired in this study. When the values, which are obtained in the end of the study by using linear multiple regression model equation (2) in the estimation process with RM, are compared to experimental data, it is seen in Figure 2 that two groups of data are very close to each other.

R is calculated as 0.926 with correlation analysis made between RM-experiment data (Figure 3). Results of the correlation suggest that two groups of data among the results obtained by models with experiment are correlated and prove that there are no differences among data in terms of meaning.

In this study, regression analyses, which are statistical approach by using data in experimental studies, are made and regression equations, which can estimate compressive strength, are composed. When experimental data and data which is obtained from developed regression models are statistically compared, it is seen that designed models give successful results. As a result, RM shows its usability in determining Tn values with this study. RM models can transform disadvantages in experimental studies into advantages. Furthermore, it has such significant advantages as interpolation which is not done in this experiment. By increasing the number of parameters in...
future studies and developing different regression models, the field of study can be expanded.

REFERENCES


Wind Power Forecasting For The Province Of Osmaniye Using Artificial Neural Network Method

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Abstract— Although wind energy at certain intervals and random in nature, today it is one of the commonly utilized alternative energy source in the world. Because of sustainability and environmentally-friendly energy source, countries increasingly benefit from wind energy. Several estimation methods are applied in the determination of a region’s wind energy potential. Today, one of the most commonly used prediction methods is artificial neural network (ANN) method. In this study, Estimation of wind power in Osmaniye district was investigated in method with artificial neural network (ANN) using data from meteorological measurement stations from the meteorological measurement device at the campus of Osmaniye Korkut ATa University. In order to give the best values of prediction results, several methods increasing the impact on output of different models for the input variables were investigated.

Keywords— Wind Power, Prediction, Artificial Neuron Network

I. INTRODUCTION

In recent years, the importance of the renewable energy sources grows worldwide. The reasons of this growth are that the sources named as fossil fuel are exhaustible, and they have negative effects on environment. Especially as a result of the gradual increase in greenhouse gases like Carbon dioxide and Methane which have direct impact on global warming, our environment is affected negatively [1]. Although there are some saving studies worldwide considering the issue of fossil fuels in energy usage, these are not enough. Because the energy need of people and corporations increase gradually. To avoid from this deficiency, renewable energy sources are used in recent years. Renewable sources are becoming one of the leading actors all around the world in the production of electric energy. In a short time, they are foreseen to become alternatives for power plants running fossil fuels, and they will become more widespread.

When the renewable energy types are considered, the first ones to remember are wind and sun. They are also the energy sources on which the highest number of research and scientific studied are conducted. The popular method to use to produce electric energy by using solar energy is to make use of radiation. While producing energy from the wind; first, the energy turns into kinetic energy, then into electric energy. The velocity of the wind is one of the most important parameters in the production of energy from the wind. For this reason, it is a must to measure both the velocity and potential of the wind in a certain area before launching a wind power plant [2]. For this reason, the researchers developed methods to predict the wind potential in recent years. These prediction methods aim at measuring the wind power of a certain area or predicting it by using certain inputs. As it is shown in (1) the power of the wind is stated as a mathematical function in which it equals the cube of the wind velocity [3].

\[
P = \frac{1}{2} \rho Av^3
\]

Equation (1) according to the formula, it is seen that the calculated or predicted value of the wind velocity grows exponentially. Hence, the wind velocity acts as a defining factor in power calculation more than other variables in the formula. This velocity variant is taken into account in the detection of establishing wind power plant into a certain place and of the identification of their performance [3]. When we have a look at the recent studies, it can be seen that the methods used to predict the velocity and power of the wind are artificial intelligent based (ANN, Fuzzy Logic, Support Vector Machine) methods. The commonly used one is the ANN method. The studied conducted by using this method are indigenous to a definite area. A model can create using the data chosen such as the latitude, longitude, elevation, and average of wind velocity (yearly, monthly, daily, hourly), their minimum and maximum velocity values, distance to the sea level, air pressure, density and temperature. These chosen data are defined as input variants in the model. These input variants are chosen by trying as many different methods as possible to do the best predictions. There are many layers in these models. The input and output are the main layers. There are one or more hidden layers between them. There are a few neurons in each layer. When a model has been created, some of the data is used for education (learning) while some of it is used for test (prediction). The aim is to predict the wind velocity and power belonging to a certain
area as output. Besides, by making use of Box-Jenkins statistical model (ARIMA-Autoregressive Integrated Moving Average) which is used to predict seasonal or non-seasonal time periods, fuzzy logic methods (ANFIS-Adaptive Network-Based Fuzzy Inference System), Genetic Algorithm based models; and by creating a hybrid or a different model with ANN, it can be used both while predicting the wind potential and while comparing the predictions. [3-11].

In our study, the short term wind power prediction with ANN is aimed using the data taken from the meteorological station which was mounted at the Campus of University of Osmaniye Korkut Ata. The data from the first half of 2013 is used (between January and June). With the aim of evaluating the prediction performances of a model created with ANN, three different statistical indicators are used such as coefficient of determination ($R^2$), Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE). The power plant potential of Osmaniye province for the first six months has been estimated using these indicators.

II. MATERIALS AND METHODS

A. The Structure of Artificial Neural Network

The artificial nerve nets were discovered in the second quarter of the 20. Century and they started to be used. It is an informatics technology developed by inspiring the data processing capacity of human brain. Generally it was emerged out of the inspiration of human brain and operation of central neural system. The principle of biological neural system is imitated with ANN. These nerve cells include neurons, and they create neural networks by binding themselves in different kinds. The created nets carry the potential of learning, remembering and finding relationship between data. In other words, they can find a solution to those problems requiring human beings’ thinking and natural observation abilities. The created nets were successfully used in different disciplines such as mathematics, engineering, medicine, meteorology, economics, computer and electronic fields [9-12].

![Fig. 1 Biological nerve cell structure of human.](image)

With the entrance and proliferation of computer systems into human life, the model in Fig. 1 is used for the problems seeking for attention. A mathematical model trying to imitate human brain cell’s operation can be defined among artificial neural networks. It has many advantageous aspects as it can be paralleled, generalized, and as it is easy to analyze and design. One of the most important features of it is its capacity to derive as much information as possible without the need to any assistance. A mathematical model of an artificial neural network and its working principle are given in Fig. 2. This structure is the process of imitating the human brain and the process of transferring learning to the computer based systems [12].

![Fig. 2 ANN Mathematical Model.](image)

B. Wind Data

The data used in our study has been provided from active meteorological stations at Osmaniye Korkut Ata University. The coordination of the station is 37.05 north and 36.14 east. It is 120 meters above the sea level. The distance from the sea is 20 kilometers. The experimental date used in the study was measured by using Vantage Pro2 meteorological measuring device. This device has been planted in the elevation of 20 m. [13].

With the aim of predicting short term wind power, Wind Velocity, Temperature And Humidity data of 2013’s first half (January-June) has been taken. The hourly averages of the data have been measured as the station measures the data every 5 minutes. The wind power of each input variables have been measured by using the strength formula in (1) as a part of emerging results. At the same time the normalization formula given in (2) has been used to capture more accurate results in models formed with ANN.

$$X_n = \frac{X - X_{min}}{X_{max} - X_{min}}$$ (2)

It is a fact that the using ANN models in measure values without doing anything gives worse performance results then using it after normalization. This situation is quite apparent in whether forecast. Min-Max normalization method is a way which provides linear normalization for data between 0 and 1. It is used commonly. It defines minimum value while describing the maximum related data’s possible peak value [14].

C. The Generated Model and Validation Methods

The best models have been tried to be created in order to estimate the wind power with MATLAB, using input
variables (Wind Velocity, Temperature, and Humidity). Multilayer Feed-Forward (FFMLP) Backprop Network has been used because of the best performance in the developed model. TRAINLM is chosen as the education function, and TRAINGDM is chosen as the learning function in this network. As an activation function, LOGSIG is used in the first layer, and TANSIG is used in the second one. Neurons are recommended to use twice as much as for the input variables at the generated hidden layer of ANN model [15]. Hence, 6, 9, 12, 15, 18, 21, 24, 27, 30, 60, and 90 neurons in the hidden layer are formed, as a result of 11, 20, 16, 19, 8, 54, 101, and 236 epoch trying, smallest MSE (Mean Square Error) test error for network capable of generalization is tried to get. Both the best performance and 30 neurons model with high velocity are formed after 16 epoch model and is shown in Fig. 3.

![Fig. 3 3 Input 1 Output ANN model.](image)

The achievement status for the developed model is necessary to compare statistically. When we look at the literature, the most widely used statistical error methods are Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE). There are also some other methods to use. Among the statistical error methods, MAPE is the most effective one in terms of making sense without other factors when it is compared with other methods [1, 3, 7-13]. MAPE and RMSE which are the statistical error methods are used in this paper. At the same time, the models have been compared by measuring the coefficient of determination (R²). MAPE, RMSE and R² formulas are given respectively in Equation (3), (4) and Fig. 4.

\[
\text{MAPE} = \frac{1}{n} \sum_{i=1}^{n} \left| \frac{P_i - O_i}{P_i} \right| \times 100 \tag{3}
\]

\[
\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (P_i - O_i)^2}{n}} \tag{4}
\]

Pᵢ and Oᵢ represent the calculated actual values in the equation of (3) and (4) respectively.

At the end of the conducted studies, R² values are seen to be at 0.99 level when examining the results of Table I. Examining MAPE, results that are above 10% are accepted to be well in success rate. Assessing the MAPE results for a prediction model or models, the values under 10% are very good, values between 10% and 20% are good, values between 20% and 50% are acceptable level. If the result of MAPE is over 50%, model should be considered as a wrong or failure [16]. If the RMSE value is 0.0015, it will show us that performance success of the model is a good level.

Regression graphic of concerned model in MATLAB program at 16 epoch result, it is seen as in Fig. 5.

![Fig. 4 Coefficient of Determination (R²) formula, y, y' and & values respectively of supplied Real, Estimate and Mean Values.](image)

### III. MODELS RESULTS

In this study, 4344 data has been used between January and June considering the hourly value. The data obtained between January and June has been put into the system as education (training), and it is aimed to predict the wind power data of June. For this reason, 3624 (83.4%) rating between January and May has been used as education, and 720 (16.6%) rating within June has been used for testing purposes. R², RMSE and MAPE results of ANN model have been given below in Table I.

<table>
<thead>
<tr>
<th>R²</th>
<th>RMSE</th>
<th>MAPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.999159</td>
<td>0.001467</td>
<td>13.79</td>
</tr>
</tbody>
</table>

At the end of the conducted studies, R² values are seen to be at 0.99 level when examining the results of Table I. Examining MAPE, results that are above 10% are accepted to be well in success rate. Assessing the MAPE results for a prediction model or models, the values under 10% are very good, values between 10% and 20% are good, values between 20% and 50% are acceptable level. If the result of MAPE is over 50%, model should be considered as a wrong or failure [16]. If the RMSE value is 0.0015, it will show us that performance success of the model is a good level.

Regression graphic of concerned model in MATLAB program at 16 epoch result, it is seen as in Fig. 5.
In these regression graphics, test, training and verification graphics of related model is seen. Performance graphic of developed model according to Mean Square Error (MSE) is given in Fig. 6.

```
Fig. 5 Regression Graphics of ANN Model
```

Generally speaking when compared statistically, obtained MATLAB results are approximately same. Comparison between actual calculation of 24-hour power estimation measurements of an arbitrary day (11th) in June and power rating with estimation of ANN model is given in Fig. 7.

```
Fig. 6 MSE Performance Graph
```

```
Fig. 7 Comparison of 11th of June between actual and estimated ratings
```

As it is well understood from the Fig. 7, success rate between estimated and actual value can be seen, it is very close to each other and this figure also shows us that the prediction method gives quite good results according to the actual value.

**IV. CONCLUSION**

In this conducted research to estimate potential wind power of Osmaniye city, feedback forward neural network is utilized by using MATLAB program. Wind power estimation of June is calculated by educated models by means of changing a series of parameters of model as hidden layer, learning and education function and neuron number in order to optimize the estimated results of created model. When estimated values compare with the actual values statistically, $R^2$ values of estimated model are quite good result and it is very close to 1 shown in Table 1, and this value determines the success rate of the estimated model substantially. Furthermore, the results of the MAPE and RMSE shows us the power of prediction of estimated model and the it is shown clearly in Fig. 7. By this means, short term wind power estimation with high success rate is made in Osmaniye.

**REFERENCES**


Performance Analysis of Spiral Neighbourhood Topology Based Local Binary Patterns in Texture Recognition

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Abstract— In many texture recognition problems, Local Binary Patterns (LBP) method is used for feature extraction. This method is based on comparison of each centre pixel and its neighbours’ intensity value in image. Due to its simplicity of calculation, LBP has become one of the most popular feature extraction techniques. In literature, different neighbourhood topologies of LBP structure are given such as circle, square, ellipse, parabola, hyperbola, and Archimedean spiral. This paper focuses on the use of uniform and basic LBP that have spiral topology in texture classification. We first derive basic and uniform LBP features based on spiral topology. Then the performances of several classification methods such as linear discriminant analysis (LDA), linear regression classifier (LRC), support vector machines (SVM), Chi-square test, and G-test are compared using these features in UIUC texture database.

Keywords— Local binary patterns, texture recognition, feature extraction, classification methods, spiral topology.

I. INTRODUCTION

Texture can be defined as a repeating pattern of local variations in image intensity. Texture contains information about the spatial arrangement of the colours or intensities in an image. Texture classification basically means that assignment of unknown image to one of known classes. Texture classification process consists of two main operations. The first operation is extracting features of the image and the second one is classification phase.

The best description of image is a very important step for classification phase of texture classification. There are a lot of feature extraction methods in literature for the best description of image. In [1], Raju and Durai presents texture classification techniques based on feature extraction in two categories according the local and global features.

Local Binary Pattern (LBP) is one of the methods which used local features. It is gray-scale invariant local descriptor which was proposed by Ojala [2] and is a powerful descriptor for texture recognition. The descriptor is used various fields of image processing problems such as shape localization [3], interest region description [4], gender classification [5], palmprint recognition [6], digital image stabilization [7] and especially face recognition problems [8]. There are a lot of improved versions of original LBP. In [9], authors present rotation invariant and uniform LBP which include fundamental information about texture. In [10], multi-dimensional LBP was proposed to using multi-dimensional histograms for different radii. Several versions of LBP were studied in [8].

The basic LBP calculates histograms with circular neighbourhood topology. Using this topology is advantage for rotation invariant problem in the texture classification application but anisotropic structural information may important features for some problems. An elliptical neighbourhood topology was used to exploit this anisotropic structural information for a face recognition system in [11].

Other variants of LBP are proposed by [12]. Different shapes such as ellipse, circle, parabola, hyperbola and Archimedean spiral for the neighbourhood calculation are tested. Different encodings to create LBP code are described for the evaluation of the local grayscale difference. According to this work, proposed quinary encoding and using elliptic neighbourhood performs the best with the medical image databases.

In the classification phase, performance of subspace based classification method is better than the statistical tests based on similarity measures [13]. We employed Chi-square test, G-test, support vector machines (SVM), linear discriminant analysis (LDA) and linear regression classifier (LRC) for the classification. LRC is one of the subspace methods [14] that is generally used for face recognition problems [15-17]. The experimental results of our study show that using LRC with SLBP features gives better results in texture recognition.

The remainder of the paper is organized as follows. Section 2 introduces the LBP operator. Our approach for computing the LBP codes is explained in Section 3 and classification methods are presented in Section 4. The experimental study performed in this paper is given in Section 5 and finally conclusions are presented in Section 6.

II. LBP

LBP proposed by Ojala et al. is one of the most famous texture descriptor. LBP operator is the grayscale invariant
texture measure. This operator works with the gray value of image pixels.

For the each pixels of an image which is defined as centre pixel, binary code is generated by comparing it and its neighbours. If the difference between compared neighbouring pixel value and centre pixel value is higher or equal to 0, compared neighbouring pixel value is coded as a binary 1, in the other case it is coded 0. Fig. 1 shows an example of LBP method.

![Fig. 1 Basic LBP Operator](image-url)

The limitation of the basic LBP operator is using 3x3 square neighbourhoods for the description of local binary pattern. To eliminate the disadvantage, the operator was extended to use different size of neighbourhood and Fig. 2 illustrates two circularly symmetric neighbour sets for different radii.

![Fig. 2 (8,1) and (16,2) LBP Operator](image-url)

Let \( LBP_{p,R} \) denote the LBP code of a pixel’s circularly neighbouring neighbourhoods, where \( P \) is the number of sample points on the circle of radius \( R \), \( g_c \) represents intensity value of centre pixel and \( g_p \) is the gray value of its \( p \)th neighbour. Then the \( LBP_{p,R} \) can be calculated as follows:

\[
LBP_{p,R} = \sum_{p=0}^{P-1} s(g_p - g_c)2^p, \quad s(x) = \begin{cases} 1, & x \geq 0 \\ 0, & x < 0 \end{cases}
\]

As a result of calculation of LBP operator, decimal number is assigned to each pixel of image. After this process, a histogram is built to represent the image and used for pattern recognition as feature.

The concept of uniform patterns is to extract fewer feature of image texture. Any LBP pattern is called as uniform (ULBP) if the binary pattern consists of at most two bitwise transitions from 0 to 1 or vice versa. For example, binary code of the pattern that given in Fig. 1 is 00101101. This pattern is not a uniform pattern because of having higher than two bitwise transitions. It has three 0-1 transitions and two 1-0 transitions. A pattern having 00011000 binary codes is uniform pattern. If each pixel in image has 8 neighbours, there are totally 58 uniform patterns. In histogram, only one bin is allocated for the all non uniform patterns so histogram consists of 59 bins.

### III. CLASSIFIERS

#### A. G-test

G-test is defined as the following equation:

\[
G(S, M) = 2 \sum_{b=1}^{B} S_b \log \frac{S_b}{M_b}
\]

where \( B \) is the bins number of the histogram, \( S_b \) and \( M_b \) represents probabilities of sample and model distributions at bin \( b \) respectively. \( S_b \log S_b \) is the same for each model during classification and there is no effect of constant scaling factor 2 on classification result so G-test can be simplified as:

\[
L(S, M) = \sum_{b=1}^{B} S_b \log M_b
\]

As a result, test sample \( S \) is assigned to \( M \) model which maximizes the \( L \) statistic.

#### B. Chi-square \((\chi^2)\) Test

Assume that we have two histograms \( S \) and \( M \) for comparison. \( \chi^2 \) test is computed as:

\[
d_{\chi^2}(S, M) = \sum_{i=1}^{B} \frac{(s_i - m_i)^2}{s_i + m_i}
\]

where \( B \) is the number of bins, \( s_i \) and \( m_i \) represents value of \( S \) and \( M \) distributions at bin \( i \), respectively. A simple nearest-neighbour rule is used for classification.

#### C. Support Vector Machine (SVM)

The purpose of SVM is to select a hyperline or a hyperplane which separates the features of two classes. If features can be separated linearly, this procedure can be applied otherwise, features are mapped onto higher dimensional space that can separate the features linearly.

#### D. Linear Discriminant Analysis (LDA)

LDA is the most commonly used as dimensionality reduction technique and maximizes the linear separability of the groups belonging to different classes in data.

The aim of LDA is to maximize the distance between distributions of classes and to minimize variation in each class. Thus it can reduce dimensionality and save the information that is used in classification process at the same time. Objective function that is maximized in LDA defined as:

\[
f(w) = \frac{S_B}{S_W} = \frac{w^T S_B w}{w^T S_W w}
\]

where \( S_B \) is between the classes scatter matrix, \( S_W \) is within the class scatter matrix.

#### E. Linear Regression Classification (LRC)

Assume that we have \( C \) classes with \( N \) training images. The matrix \( W_i \) contains all feature vectors from \( i \)th class. Thus

\[
W_i = [x_i^1; \ldots; x_i^1; \ldots; x_i^N]
\]
where $\chi^j_i$ represents the $j$th feature vector of the $i$th class. If $y$ belongs to the $i$th class, it should be represented as a linear combination of the training images from the same class and can be defined as

$$y = W_i \beta_i + \epsilon$$  \hspace{1cm} (7)

where $\beta_i$ is the vector of parameters that is estimated using least squares estimation. Hence the estimation of $\beta_i$ is

$$\hat{\beta}_i = (W_i^T W_i)^{-1} W_i^T y$$  \hspace{1cm} (8)

The estimation of the vector $y$ is calculated as follow:

$$\hat{y}_i = W_i (W_i^T W_i)^{-1} W_i^T y$$  \hspace{1cm} (9)

The minimum distance between the original vector and the projected vector is calculated according to the Euclidean distance measure, i.e.,

$$\text{argmin}_i \{||y - \hat{y}_i||\}, \hspace{1cm} i = 1, 2, ..., C.$$  \hspace{1cm} (10)

IV. SPIRAL LOCAL BINARY PATTERN (SLBP)

We introduced basic encoding LBP operator with spiral topology for texture recognition in this section. The basic LBP calculates histograms with circular neighbourhood topology. Using this topology provides rotation invariant but cannot exploit the anisotropic structural information. This information may an important source in some problems. An elliptical neighbourhood topology has been used to exploit this anisotropic structural information for a face recognition system in [11].

Other variants of LBP are proposed by [12]. Different shapes such as ellipse, circle, parabola, hyperbola and Archimedean spiral for the neighbourhood calculation have been tested and different encodings have been used for the evaluation of the local grayscale difference. According to this work, proposed quinary encoding and using elliptic neighbourhood gives the best accuracy with the medical image databases.

The equation of the Archimedean spiral is expressed in terms of polar coordinates such as ($r, \theta$). The equation of Archimedean spiral can be described as follows

$$r = a + b \theta$$  \hspace{1cm} (11)

where $a$ and $b$ can be any real numbers. Changing the parameter $a$ turns the spiral, while $b$ controls the distance between the turnings. Fig. 3 illustrates an example of spiral neighbourhood which we used to extract features.

Each pixel in the image is selected as the centre point respectively. Black circle is the centre pixel and its eight neighbours are represented as blue stars in Fig. 3.

The neighbour points are identified by choosing theta intervals of $\pi/4$. If a point doesn’t overlap to the centre of the pixel, the intensity value of the point is interpolated by bilinear interpolation.

Calculation of LBP code is the same as basic LBP for SLBP. Firstly the nearest neighbour of centre pixel is compared and then comparison continues towards the farthest one. Consequently binary code is generated depending on whether the central pixel is higher than or equal to neighbours. Obtained binary code is converted to decimal value and this value is labelled to centre pixel. Finally, histogram of decimal values is created.

Uniform spiral LBP (USLBP) is determined like uniform LBP and non uniform ones correspond to only one bin in histogram.

V. EXPERIMENTAL RESULTS

This section describes experiments that show the efficiency of the proposed spiral neighborhood topology for texture classification.

UIUC texture database which involves 40 textures from each of 25 textures is used for evaluation. Fig. 4 shows example images from each class (the resolution of the samples is 640×480 pixels). Samples of each class have different viewpoint and scale differences. Furthermore, the dataset includes non-rigid deformations, illumination changes and viewpoint-dependent appearance variations.

To get statistically significant experimental results, 30 training images are randomly selected from each class of UIUC database while the remaining images per class are used as the validation set.

The Archimedean spiral starts in a centre pixel and makes a curve with one round ($2\pi$). So 8 sampling points on a spiral are computed intervals of $\pi/4$. Sampling points which do not overlap to centre of a pixel are computed by bilinear interpolation. In (11), $b$ parameter is set as 0.3 for the best performance of spiral neighbourhood topology.

All texture images of UIUC database are represented by LBP, ULBP, SLBP and SULBP histograms. The LBP codes are computed using 8 sampling points on a circle of 1 radius for comparison with SLBP.

The extracted features are classified with Linear SVM, LDA, LRC, Chi-square test and G-test for measure of dissimilarity between features.

The classification algorithms are implemented ten times independently. The average classification accuracies obtained with different texture databases are shown in Table I. The best recognition result achieved is 85.64% with LRC where the SLBP features of UIUC database is selected as shown in Table I as bold and underlined style.
Performance of proposed SLBP is higher than the other feature extraction methods for all classification methods. The statistical tests based on similarity measures perform worse from subspace based methods. LRC is the best classification method in UIUC texture database as a result of experiments.

![Image](https://example.com/image.png)

Fig. 4 Sample images from UIUC texture dataset.

<table>
<thead>
<tr>
<th></th>
<th>LBP</th>
<th>ULBP</th>
<th>SLBP</th>
<th>SULBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-test</td>
<td>±3.40</td>
<td>±3.00</td>
<td>±3.72</td>
<td>±3.04</td>
</tr>
<tr>
<td>±1.98</td>
<td>±1.92</td>
<td>±2.73</td>
<td>±3.00</td>
<td></td>
</tr>
<tr>
<td>Chi-square</td>
<td>±6.34</td>
<td>±6.17</td>
<td>±6.38</td>
<td>±6.76</td>
</tr>
<tr>
<td>±2.35</td>
<td>±3.01</td>
<td>±2.81</td>
<td>±2.40</td>
<td></td>
</tr>
<tr>
<td>SVM</td>
<td>±6.34</td>
<td>±7.42</td>
<td>±8.04</td>
<td>±6.92</td>
</tr>
<tr>
<td>±2.35</td>
<td>±3.87</td>
<td>±2.55</td>
<td>±3.59</td>
<td></td>
</tr>
<tr>
<td>LDA</td>
<td>±79.96</td>
<td>±80.16</td>
<td>±83.32</td>
<td>±83.72</td>
</tr>
<tr>
<td>±3.50</td>
<td>±3.20</td>
<td>±2.60</td>
<td>±3.04</td>
<td></td>
</tr>
<tr>
<td>LRC</td>
<td>±84.44</td>
<td>±83.28</td>
<td>±85.64</td>
<td>±84.36</td>
</tr>
<tr>
<td>±2.34</td>
<td>±1.45</td>
<td>±1.91</td>
<td>±2.19</td>
<td></td>
</tr>
</tbody>
</table>

### VI. CONCLUSIONS

In this paper, we have presented uniform and basic Local Binary Pattern (LBP) with Archimedean spiral neighbourhood topology to texture recognition. Firstly, we derived basic and uniform LBP features based on spiral topology. Then the performances of several classification methods such as linear discriminant analysis (LDA), linear regression classifier (LRC), support vector machines (SVM), Chi-square test, and G-test are compared using these features. Experimental results obtained from UIUC texture database clearly demonstrate that the best recognition rate is obtained with using SLBP features and LRC method. In the future, we plan to focus on improving spiral topology to obtain more meaningful information.

### REFERENCES

WAREHOUSE DESIGN APPLICATION WITH VIP PLANOPT IN A MANUFACTURING COMPANY

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ABSTRACT

If storage systems are well analyzed and if method of storage is well-known, we can save time, energy and money. Therefore, a successful warehouse management is significant for companies. Efficient warehouse management is possible with effective warehouse design applications. In this study, a warehouse design model is developed. In this model, a hybrid heuristic algorithm is used for solution of design problem. We use VIP-Planopt for application. It is a flexible software program that enables us to enter specific constraints. VIP-Planopt is optimization software that produces optimal or near-optimal layouts. In the application, we study with eight different structured big shelves in a manufacturing company warehouse. As a result of application, we found a new and better warehouse design minimizing total material flows. We discuss application results with algorithm outputs in detail in the study.

Keywords: Plant layout, Warehouse management, VIP-Plant Optimization.

I. INTRODUCTION AND LITERATURE

Warehouses are temporary storage points used during the distribution of the products. Warehouses make significant contribution to the effective implementation of the logistic activities and the operation of the supply chains in accordance with the target goals. Warehouses can be located in or near the manufacturing plants and also can be built separate and special complexes. Stores/products are stored in the shelves in various items, the entry and exit of the products are carried out by means of loading ramps and loading and unloading processes are made by using forklift trucks.

In order to understand to what extent the storage takes place in the supply chain, it is necessary to comprehend the basic stores/products distribution strategies firstly. The three basic strategies used in the distribution of the stores/products are the following: [1]

- **Traditional Distribution:** In this type of distribution, which is made through warehouses, warehouses are temporary storage points for products. In this strategy, functions like goods acceptance, arranging on shelves, storage, consummation, order collection, packing and shipment/delivery are carried out.

- **Direct shipment:** It is direct transmission of the products from supplier to the customer.

- **Cross-docking:** The products received from the supplier are sent to the customer by keeping them temporarily (less than 24 hours) without storing in the warehouses called cross-docking plants.

In order to carry out the production and service systems effectively, not only the implementation of optimum plans and operational policies, but also a good projection is required. The optimum design of the physical layout is a crucial topic that should be considered in the early stages of the projection. [2]. The studies on the design of the plant layout are generally required as a result of the changes in the ground requirements, people or equipments [3]. An efficient plant projection decreases the time of delivery, increases the outputs and as a result, increases the efficiency of the plants. [4]

The plant layout design is one of the most important issues that affect the efficiency of a production system. The plant layout is crucial for companies and an inseparable part of planning process. Plan Layout Problem (PLP) is interested in arranging the physical sectors in a plant for the efficient operation of a plant. PLP has been subject to many researches because of its interdisciplinary importance. According to Jajodia vd., a good solution to the PLP contributes to all activities. A bad layout causes the stocks to pile up, the
product transport systems to be overloaded, the time for preparation to increase and product queues to be longer [5]. Therefore, the solution to PLP is a strategical stage for all enterprises.

Generally, two different approaches are being used to solve PLP. One of them is the qualitative approach which tries to maximize the total amount of the proximity scores among the sectors. Systematic Layout Planning procedure developed by Muther [6] is one of the most important studies on this issue. The second one is the quantitative approach which tries to minimize the total amount of the product transport costs among sectors. The study made by Armour and Buffa [7] can be shown as a good example for his approach.

Many studies in the literature have used the qualitative and the quantitative approaches separately so as to solve the PLP. However, many researchers questioned whether it is logical to consider only one criterion to solve the PLP. Both of the approaches have some advantages and disadvantages [8]. However, those models which are based on only one criterion is not explanatory, because there are too many factors to affect the plant layout. In fact, PLP should include both the qualitative and the quantitative criteria. For this reason, it is in the category of multi-functional plant planning projection problem. [9].

According to Malakootii, the aim of the multi-functional plant layout planning is to produce efficient layout plan choices to be given to the decision maker. Thus, the decision maker can prefer the best layout plan option by considering the conflicting aims. There are three different methods to solve this problem. One of the is to find out the proactive cluster of the layout plan options and to submit them to the decision maker. The second one is that the preferences of the decision maker are found out first and then the optimum layout plan option is indicated according to these preferences. The third one is to use an interactive way to find out the optimum layout plan option. [10].

In order to solve the multi-functional plant layout planning problem, many studies have been carried out. In many of these studies, predetermined loads has been given to each goal and combined and only one goal has been acquired in order to indicate the optimum layout plan option. The quadratic assignment problem formulation has been used to model the multi-functional plant layout planning problem.

In this study, an optimal solution has been targeted by using VIP-Plant Optimization program for plant layout problem. Different from the methods mentioned in the literature, the convenient plant layout has been found out by using a package program. In addition, some information about the abovementioned program has been given in this study and it has been aimed to shed light on many problems’ solutions.

II. PLANT LAYOUT WITH VIP-PLAN OPTIMIZATION PROGRAM

VIP-PLANOPT is an important solution instrument for plant designing problems in engineering, industrial planning and plant designing. VIP-PLANOPT (Visually Interfaced Package of PLANOPT) is a package software program developed to produce optimum layouts for blocked or modular problems that have small, medium or large scaled unequal rectangular dimensions. The term “optimum layouts” means locating the certain number of modules in the Euclidean space in the best way without any extensions out.

A. Optimization Algorithm

The PlanOPT optimization algorithm is a research product. It is a robust, registered and hybrid algorithm. The Algorithm occurred as a result of the development of a technic that was producing better results and developed by two university professors to solve the KAP in unequal sizes in 1995.

VIP PlanOPT 2006 has reinforced its superiority over the other algorithms by making the following additions to this algorithm.

In order to bring the variability of the algorithm observed in some circumstances, double-precision arithmetic has been added.

- In order to decrease the dependence on the starting point determined by the user, new technics has been added.
- In order to provide the optimal layout within boundaries with complicated and mixed shapes and simple rectangular shapes determined by the user, punishment functions has been added.

The user interface screen of the program is shown in Attach-1.

B. Terms Used in the Program

Modul: The term “modul” used fort he rectangular blocks stands for the functional units like sectors, machines, rooms and areas. The size of a module along with the x line stands for its length and the size along with the y line stands for its width, and they are shown with the symbols L, and W.

The Modul width-length rate: This rate is described as the rate of the width of a module to its length. If the width-length rate for a i modul is shown as R, it can be shown as the followig equality:
\[ R_i = \frac{W_i}{L_i} \]

**The Modul area:** For an i modul, the area of the modul is calculated in the multiplication of the width and length of \( A_i \), and ve it can be shown as in the following equality.

\[ A_i = W_i \times L_i \]

**The Modul Type:** There are two basic modul types in the PLANOPT software. They are described as solid and flexible. The size of the solid modules is determined by the user and these sizes cannot be changed during the optimization. The user can determine the modul type himself/herself. The areas of a flexible modul are stable but its sizes can be changed during the optimization. The part related to the model is shown in the Attach-2. The required features of each modul can be entered in this part.

**Surrounded area:** This term is being used for the rectangular layouts involving all modules. The user can indicate the width and length of the area in which he/she will locate the modules by means of the program. This part is shown in the Attach-3. The layout can be determined by entering the coordinates or manually.

**Flow Matrix:** This matrix provides the product, hardware and staff flow in all pairs of modules. One component of this matrix shows the flow among \( f_{ij}, i \) and \( j \) modules. This flow can be explained as the unit load carried in a unit of time between two modules.

**Unit cost matrix:** This matrix shows the cost of transport of a unit load to a unit distance among all pairs of modules. One component of this matrix shows the cost of transport of a unit load to a unit distance among \( u_{ij}, i \) and \( j \) modules.

**C. Cost Functions**

PLANOPT finds out the optimal layout by minimizing the the aim function. The program uses four different aim (cost) functions. The cost functions are shown in the Attach-4.

**Cost function F1:** This function is used when the cost matrix is symmetrical. The formulation of the function is:

\[ F1 = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f_{ij} \times u_{ij} \times d_{ij} \]

**Cost function F2:** This function is used for layout problems in which function cost matrix is both symmetrical and dissymmetrical. The formulation of the function is:

\[ F2 = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij} \times u_{ij} \times d_{ij} \]

**Cost function F3:** This function is used when the cost matrix is symmetrical. This is a composit function. The formulation of the function is:

\[ F3 = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f_{ij} \times u_{ij} \times d_{ij} + \omega \times A_B \]

\( AB \) in the formulation expresses the area of rectangular layout; \( \omega \) expresses the weight determined by the user on this area.

**Cost function F4:** This function is used for office planning problems in which the cost matrix is not symmetrical. This is a composit function. The formulation of the function is:

\[ F4 = \sum_{i=1}^{n} \sum_{j=1}^{n} f_{ij} \times u_{ij} \times d_{ij} + \omega \times A_B \]

**III. IMPLEMENTATION**

For implementation, the optimum layout of a warehouse with 8 shelves has been chosen. The optimum layout plan has been calculated by entering the different physical features of the shelves. Data is shown in the Attach-5. The flows among the shelves should be indicated for the optimal arrangement of the shelves in the plant layout. The cost will be calculated after these flows. The flow matrix is shown in the Figure 1.

![Flow Matrix](Attach-6)

**Figure 1. Flow Matrix**

After the entry of probe data, the optimum layout plan has been generated by a solution with 6 iterations. According to the "F1" cost function, a cost has been calculated. The optimal layout plan is shown in the Attach-6.

The cost results about the solution has been shown in the Attach-7.
IV. CONCLUSION AND EVALUATION

It has been seen in the literature research and implementation that the optimum layout for the factory has been found with the method used, but the important points are that the solution should be convenient for the operation of the factory and the real life. In other words, it should be feasible. In this study, studies about the plant layout planning problem which is one of the most important and basic issues in production systems has been reviewed and then an optimum layout plan has been acquired through real data taken from a real production system by using VIP-PLANOPT software. In the implementation stage, 8 shelves with different features and the relations with each other has been indicated and the convenient layout plan has been emerged.

REFERENCES


ATTACHMENTS
Attach-1. The Interface Screen Of VIP-PLANOPT Software Program

Attach-2. Modul Data
Attach-3. The Interface Used for Surrounded Area

Attach-4. The cost functions

<table>
<thead>
<tr>
<th>Simple Symmetric</th>
<th>Simple Non-Symmetric</th>
<th>Composite Symmetric</th>
<th>Composite Non-Symmetric</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sum_{i=1}^{n-1} \frac{\alpha_{ij}}{d_{ij}}$</td>
<td>$\sum_{i=1}^{n} \frac{\alpha_{ij}}{d_{ij}}$</td>
<td>$\sum_{i=1}^{n-1} \frac{\alpha_{ij}}{d_{ij}} + a_A$</td>
<td>$\sum_{i=1}^{n} \frac{\alpha_{ij}}{d_{ij}} + a_A$</td>
</tr>
</tbody>
</table>

Attach-5. The Features of the Shelves Determined For the Implementation

<table>
<thead>
<tr>
<th>ID</th>
<th>Type</th>
<th>Mobility</th>
<th>Orientation</th>
<th>Area</th>
<th>Length</th>
<th>Width</th>
<th>X-LLC</th>
<th>Y-LLC</th>
<th>AR-LB</th>
<th>AR-UB</th>
<th>AR-Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hard</td>
<td>Moveable</td>
<td>Fixed</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>N/A</td>
<td>N/A</td>
<td>1.5</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Hard</td>
<td>Moveable</td>
<td>Fixed</td>
<td>30</td>
<td>5</td>
<td>6</td>
<td>N/A</td>
<td>N/A</td>
<td>1.2</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Hard</td>
<td>Moveable</td>
<td>Fixed</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Hard</td>
<td>Moveable</td>
<td>Fixed</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Hard</td>
<td>Moveable</td>
<td>Fixed</td>
<td>8</td>
<td>2</td>
<td>4</td>
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<td>N/A</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Hard</td>
<td>Moveable</td>
<td>Fixed</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Hard</td>
<td>Moveable</td>
<td>Fixed</td>
<td>16</td>
<td>4</td>
<td>4</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Attach-6. Optimal Layout Plan

Attach-7. Cost Results

Cost Function Minimized:

\[ F_1 = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f_{ij} u_{ij} d_{ij} \]

<table>
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<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
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<td>F_1</td>
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<tr>
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<td>Distance Norm</td>
<td>Squared Euclidean</td>
</tr>
<tr>
<td>3</td>
<td>Function Type</td>
<td>Simple</td>
</tr>
<tr>
<td>4</td>
<td>Weight on Area</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Optimization Seed</td>
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</tr>
<tr>
<td>6</td>
<td>Boundary Constraint</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>Module Padding</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>Distance Constraints</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>Enclosure Aspect Ratio</td>
<td>Not specified</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>VIP-PLANOPT</th>
<th>User's Modified...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>132</td>
<td>Not modified</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>1.090909</td>
<td>Not modified</td>
</tr>
<tr>
<td>Length (along x)</td>
<td>11</td>
<td>Not modified</td>
</tr>
<tr>
<td>Width (along y)</td>
<td>12</td>
<td>Not modified</td>
</tr>
<tr>
<td>Cost</td>
<td>772</td>
<td>Not modified</td>
</tr>
</tbody>
</table>

[Import user's layout]

[Export displayed layout]
PERFORMANCE EVALUATIONS FOR OPENMP ACCELERATED TRAINING OF SEPARABLE IMAGE FILTER

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Abstract—One of the widespread image processing applications is image filtering with two dimensional convolution. Determining the weights of image filters are of importance for the success of filtering operation. Heuristic algorithms such as genetic algorithms provide an efficient way of training these types of filters. Due to the high computational cost of repetitive image filtering operations, this process may take hours to implement using single core computing. OpenMP (Open Multi Processing) provides an efficient library for utilizing the computing power of multicore processors. In this study, OpenMP accelerated training of separable filters that are a subclass of convolution filters has been implemented based on genetic algorithms. Comparative speed-up results for various sizes of images using various sizes of filtering kernels were presented. Also the effect of population size of genetic algorithm and the number of working cores have been investigated.

Keywords—OpenMP, separable filters, image processing, genetic algorithms

I. INTRODUCTION

Image filters are widespread operators in image processing applications such as image enhancement, image smoothing, edge detection and noise elimination [1]. Linear filtering using two dimensional convolution or correlation is one of the main filtering operations. This is realized by applying the filtering kernel to each pixel of input image where the kernel is a matrix of weights. The size of the matrix can be 3×3 or 5×5 larger such as 21×21. If the kernel has symmetric properties, it can be expressed as the multiplication of a row and column vectors. This form is called as separable filter and it reduces the number of multiplication/addition operations.

The values of the filter weights are determined according to the desired behaviour of the filter. Weights can readily be obtained using different analytical techniques [2], [3]. In another approach, the kernel weights can be trained using the original and noisy image samples [4]–[7]. Heuristic algorithms provide an efficient way for the computation of the filter kernel weights [8]–[10]. One of the well-known heuristic algorithms is Genetic algorithm which provided its efficiency in various researches. Genetic algorithm is selected to train the weights of the separable filter. In the application of genetic algorithms, a fitness function is used to define the problem. In the present case, fitness functions is formed according to mean squared value of original and noisy images. For the computation of fitness function, intense multiplication and addition operations are carried out to obtain fitness value. Furthermore, computation time depends on the number of weights as well as the image size. During computations, fitness function is called at each iteration of the genetic algorithm. This significantly slow down the process and make the applications impractical. A method for the acceleration of the process is to utilize the computational power of multicore processor. For this purpose, OpenMP provides a useful tool for efficient use of the cores of a multicore processor. OpenMP helps distribute the computational load to defined number of threads.

In the present study, OpenMP is utilized to accelerate the computation of fitness function. Fitness function is computed for all individuals in the population and these operation can be realized independently on processor cores. In the experiments, an eight core computer is used and the results are obtained against the number of cores to see the effect of the number of cores. Also various filter kernel sizes, image sizes and the population sizes used in the experiments to show the efficiency of the OpenMP based acceleration.

II. SEPARABLE IMAGE FILTERS

Separable image filters are used in a slightly different way from the non-separable filters. An example of non-separable image filter is shown by Fig. 1 which has size 3×3. The filter kernel has a total of 9 weights. This means that the image filtering process train weights number of genetic algorithms is 9. When the size of the filter kernel grows, it is increasing training time of genetic algorithms. For instance, 25 weights for the filter kernel with 5×5, 49 weights for the filter kernel with 7×7, 81 weights for the filter kernel with 9×9, etc. The growth of genetic algorithms filter kernel increases the training time. The 3×3 filter kernel used in separable image filter is shown in Fig 1. This filter kernel which horizontal and vertical vectors as shown in Fig. 2 in the separable image filter is used.
The product of this vector also gives the filter kernel shown in Fig. 1.

\[
\begin{bmatrix}
1 & 2 & 1 \\
2 & 4 & 2 \\
1 & 2 & 1 \\
\end{bmatrix} \times \begin{bmatrix}
1 \\
2 \\
1 \\
\end{bmatrix} = \begin{bmatrix}
1 \\
2 \\
1 \\
\end{bmatrix}
\]

Fig. 2 Separable image filter is used filter kernel

Separable image filtering process can be divided into two stages. The first stage is to filter noisy image using one of the vectors. The second stage is to filter the resulting image from the first stage using the other vector. Therefore, image filtering process is completed in two stages. Separable image filter has the advantage of reduced number of weights over non-separable filter. For example, the number of filter weights to be trained in separable image filter for $5 \times 5$ is 10, while it is 25 for non-separable image filter.

### III. GENETIC ALGORITHMS

Genetic algorithm is a search and optimization method which is based on natural selection [7], [12], [13]. Genetic algorithms randomly generate multiple solutions. Bad solutions are eliminated in the next generation. Therefore, best solutions appear as the best solutions transferred to next generations.

- **Initial population**
- **Fitness**
- **While (termination criteria is not met)**
  - **Selection**
  - **Crossover**
  - **Mutation**
  - **Fitness**
- **End while**

Fig. 3 Genetic algorithm steps

Genetic algorithm involves applying selection, crossover, mutation and Fitness calculations on candidate population which are initially formed randomly. A pseudo code illustrating the operation of genetic algorithms is shown in Fig. 3. In the present case, computationally most intensive part is calculating the value of the fitness function due to the image filtering operations.

### IV. OPENMP (OPEN MULTI PROCESSING)

OpenMP is an application programming interface (API) which provide opportunity parallel computing on multicore processors. The calculations are done on multi-core processor architectures OpenMP thanks to coequally distribute all core [14].

OpenMP Architecture is shown figure 4. OpenMP, compiler directives, runtime library and environment variables are comprised from. Programmers write the code to run concurrently by putting special comments in that codes. For instance “#pragma omp parallel”. This study was parallelization of the fitness value calculating for “for” block.

OpenMP’s operation diagram is shown in Fig 5. OpenMP is identified one of the threads as main thread. Tasks are distributed in equal amounts other threads by the main thread. Due to the fact that this study was developed with C programming language, to use the OpenMP function “#include <omp.h>” as is included in the project.

Fig. 6 shows the area of the genetic algorithms parallelization process on the flow chart. This block is calculated fitness function value. This block contains computationally intensive mathematical operations. Therefore parallelization process is performed here.
V. EXPERIMENTAL RESULTS AND DISCUSSION

Experimental studies on Windows Server 2012 Essentials™ 64-bit operating system, Quad-Core AMD Opteron™ 2378 2.40GHz dual processor, 18GB Ram, have been working on computer servers. The algorithm is written in C programming language. In the experiments, 256×256, 512×512 and 1024×1024 with a pixel size images are used [15]. 3×3, 5×5 and 7×7 sizes filter masks are used for images filtering process. The developed algorithm was running 10 times for each image and at the end of working, these 10 average MSE (Mean Squared Error) value and average times for each image and at the end of working, these 10 average MSE (Mean Squared Error) value and average training time are taken. The number of population for analysing the impact of population on training time while 100 and 200 were obtained results determined separately. The number of iterations has been fixed at 400 for all calculations. Mutation rate 0.005 and crossover rate 0.3 is defined as the constant. Termination criteria of genetic algorithms are defined as the number of iterations. Noisy image used were obtained by adding Gaussian noise on the original image.

TABLE 1

<table>
<thead>
<tr>
<th>Image Size</th>
<th>1 Core</th>
<th>2 Core</th>
<th>4 Core</th>
<th>6 Core</th>
<th>8 Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>256×256</td>
<td>3.43</td>
<td>1.71</td>
<td>0.90</td>
<td>0.75</td>
<td>0.50</td>
</tr>
<tr>
<td>512×512</td>
<td>14.81</td>
<td>7.17</td>
<td>4.06</td>
<td>3.25</td>
<td>2.88</td>
</tr>
<tr>
<td>1024×1024</td>
<td>55.52</td>
<td>29.11</td>
<td>16.28</td>
<td>12.83</td>
<td>12.27</td>
</tr>
</tbody>
</table>

TABLE 2

<table>
<thead>
<tr>
<th>Image Size</th>
<th>1 Core</th>
<th>2 Core</th>
<th>4 Core</th>
<th>6 Core</th>
<th>8 Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>256×256</td>
<td>6.74</td>
<td>3.20</td>
<td>1.70</td>
<td>1.58</td>
<td>0.94</td>
</tr>
<tr>
<td>512×512</td>
<td>25.93</td>
<td>14.60</td>
<td>8.10</td>
<td>6.20</td>
<td>5.59</td>
</tr>
<tr>
<td>1024×1024</td>
<td>107.02</td>
<td>55.85</td>
<td>34.34</td>
<td>24.66</td>
<td>23.07</td>
</tr>
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</table>

TABLE 3

<table>
<thead>
<tr>
<th>Image Size</th>
<th>1 Core</th>
<th>2 Core</th>
<th>4 Core</th>
<th>6 Core</th>
<th>8 Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>256×256</td>
<td>3.97</td>
<td>2.02</td>
<td>1.13</td>
<td>1.00</td>
<td>0.62</td>
</tr>
<tr>
<td>512×512</td>
<td>16.16</td>
<td>8.79</td>
<td>4.86</td>
<td>3.61</td>
<td>3.03</td>
</tr>
<tr>
<td>1024×1024</td>
<td>68.75</td>
<td>34.85</td>
<td>19.67</td>
<td>14.03</td>
<td>12.42</td>
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</table>

TABLE 4

<table>
<thead>
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<th>Image Size</th>
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<th>4 Core</th>
<th>6 Core</th>
<th>8 Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>256×256</td>
<td>8.47</td>
<td>4.24</td>
<td>2.30</td>
<td>1.74</td>
<td>1.16</td>
</tr>
<tr>
<td>512×512</td>
<td>32.46</td>
<td>17.08</td>
<td>9.33</td>
<td>6.96</td>
<td>5.80</td>
</tr>
<tr>
<td>1024×1024</td>
<td>138.97</td>
<td>69.68</td>
<td>38.47</td>
<td>27.50</td>
<td>23.81</td>
</tr>
</tbody>
</table>
Table 1 and Table 2 shows the computational times for 3×3 window using 100 and 200 populations respectively. Table 3 and Table 4 shows the computational times for 5×5 window using 100 and 200 populations respectively. Table 5 and Table 6 shows the computational times for 7×7 window using 100 and 200 populations respectively. All results show that as the number of cores increased, the computational times reduces significantly. Figure 8a to 8f show the graphical comparison of the results. Best acceleration rates are obtained for 256×256 image.

### Table 5
**Computation times for 100 population and 7×7 filter kernel.**

<table>
<thead>
<tr>
<th>Image Size</th>
<th>Core Numbers (TIME (Minute))</th>
<th>1 Core</th>
<th>2 Core</th>
<th>4 Core</th>
<th>6 Core</th>
<th>8 Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>256×256</td>
<td></td>
<td>4.03</td>
<td>2.29</td>
<td>1.27</td>
<td>1.14</td>
<td>0.69</td>
</tr>
<tr>
<td>512×512</td>
<td></td>
<td>19.27</td>
<td>9.65</td>
<td>5.68</td>
<td>3.86</td>
<td>3.00</td>
</tr>
<tr>
<td>1024×1024</td>
<td></td>
<td>77.81</td>
<td>38.79</td>
<td>21.85</td>
<td>15.63</td>
<td>12.29</td>
</tr>
</tbody>
</table>

### Table 6
**Computation times for 200 population and 7×7 filter kernel.**

<table>
<thead>
<tr>
<th>Image Size</th>
<th>Core Numbers (TIME (Minute))</th>
<th>1 Core</th>
<th>2 Core</th>
<th>4 Core</th>
<th>6 Core</th>
<th>8 Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>256×256</td>
<td></td>
<td>9.54</td>
<td>4.75</td>
<td>2.64</td>
<td>2.02</td>
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<tr>
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<td>157.92</td>
<td>80.12</td>
<td>42.75</td>
<td>29.94</td>
<td>24.52</td>
</tr>
</tbody>
</table>
VI. CONCLUSIONS

In this study, OpenMP with accelerated training of separable image filter were analysed. In the experimental results, various sizes of kernels, and images and population sizes were tested. According to the results, doubling the population size has an increasing effect when the speed-up values on the average. Increasing the kernel size doesn’t change the results much. In general, the results show significant accelerations over single core running durations. For future studies the results will be obtained on a machine to see the efficiency limit of the number of cores.

REFERENCES


A Preliminary Survey on the Security of Software-Defined Networks

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Abstract—The number of devices connected to the Internet is increasing, data centers are growing continuously and computer networks are getting more complex. Traditional network management approach is becoming more difficult and insufficient. Software-Defined Networks (SDN) is a new generation networking approach which is expected to take place of the traditional computer networks. SDN architecture provides effective management of the large and complex networks. Although SDN have benefits from the network security perspective, it also brings new attack vectors. We believe that the network security problems in SDN architecture need more advanced solutions. In this work, a survey on the SDN security problems is presented, challenges are discussed. In this context, security threats and attack surfaces in SDN are described, the significant SDN security solution examples in the literature are given.

Keywords—Software-Defined Networks, SDN, SDN Security

I. INTRODUCTION

There are many network devices in computer networks such as router, switch, firewall, Intrusion Detection System (IDS) and Intrusion Prevention System (IPS). Complex and different protocols are running on these devices. Every day, new technologies such as Internet of Things (IoT), smart cities and smart management are emerging, data centers are growing and the number of devices in computer networks is increasing. Computer networks are getting more complex and heterogeneous and management of the network is becoming more difficult. Traditional network management approach is insufficient in large-scale computer networks. There is a need for a better network management approach and new methods. Software-Defined Networks (SDN) is an emerging concept that bring a new generation network management approach which is expected to take place of the traditional computer networks. SDN promise administrative convenience, hardware-independent, dynamic, scalable and flexible networking architecture. SDN provide a centralized network management and a global perspective on the network. So, this enables effective management of the large and complex networks.

With the rising of popularity of the IoT concept recently, the number of devices connected to the Internet increases every day. IoT offers an environment that interact the objects we use in daily life with the other objects. All of devices that support networking technology such as computers, smart phones, tablets, air conditioners, refrigerators, cars etc. continuously produce data and this data is growing each day. As a result, big data concept emerges that represents high-volume, complex and irregular data. Big data can not be processed, stored and managed by traditional methods. Big data which becomes more valuable requires meaningful results. So, big data should be processed. Big data needs more bandwidth for processing. Nowadays, smart cities and smart management concepts come to the fore more and SDN management, security and optimization topics will need more advanced mechanisms.

In the second section of this study, the basic concepts of SDN, the benefits of SDN architecture are explained. In the third section, security threats and attack surfaces in SDN are described. In the fourth section, significant SDN security solution examples in the literature are given. In the last section, this study is summarized and future works are presented.

II. SDN & BENEFITS

There are three planes/layers including application, control and data and two interfaces including application-control and control-data. Control plane decides where frames/packets will be forwarded/routed. The data plane forwards the traffic to the destination. Routers and switches that we used in today, includes control plane and data plane are integrated on the same hardware. SDN concept is based on the idea of the separation of these planes. Control plane in other words network intelligence is moved to a high performance server and network management is performed with centralized controller software. The data plane is left on OpenFlow-enabled router or switch and is responsible for forwarding of packets only. SDN architecture is shown in Figure 1. This architecture provides ability to directly programming the network and enables underlying infrastructure layer to be abstracted for network services and applications [1]. So this provides more dynamic, flexible, scalable platform and easy
management of the network compared to traditional network infrastructures.

SDN architecture brings some benefits from the security perspective. SDN provides programmability and centralized controller has a global view on the network. These characteristics of SDN have an advantage against security threats. For example, when an anomaly is detected on the network, related traffic can be sent to the controller for analyzing. After the analysis process, existing rules can be updated or new rules can be created for prevent attacks.

SDN benefits are obvious. It is expected that SDN will replace the traditional computer networks in the near future. SDN also have some security threats which will be discussed in the next section.

III. SDN SECURITY THREATS & ATTACKS

SDN architecture has network programmability and centralized control advantages but these advantages can lead to new security threats and increase of the attack surfaces. There are variety of security threats targeted to the plane and interface of the SDN. Security threats and attack surfaces in SDN are shown in Figure 2.

Security threats in SDN can be classified as seven different threat vectors, three of which are SDN-specific [3]. The security threats such as Denial of Service (DoS), unauthorized access, data leakage, data modification, malicious applications which are seen in all other network architectures is also seen in SDN [4]. The SDN specific ones are the attacks which target the controller software, communication between the control plane and the data plane (control-data interface) and the communication between the control plane and the application plane (controller-application interface). All those threat vectors have a potential effect on the operation of the entire network. Attacks against SDN planes and interfaces and the targeted security services are given in Table I.

DoS and Distributed Denial of Service (DDoS) attacks against the controller and flow table flooding attacks against the switches in the data plane target the availability principle or service of the security. One of the main features of the SDN is the logically centralized controller. Although this feature provides a global perspective on the network, it emerges as one of the major weaknesses in terms of security of the SDN architecture. In [3], it is shown that the faked traffic flows can be used to make DoS attacks to OpenFlow switches and controller sources. The attacker may expose DoS attacks to the controller by sending too many packets to the controller. Similarly, more than one attacker or botnets may send large amount of packets to the switches in a systematic way. As not all of the rules are included in the flow tables of switches, this will cause a large number of queries to be sent to the controller. In this case, the controller will be exposed to DDoS attack and will become unable to respond to legitimate requests. DoS and DDoS attacks on the controller have a potential affect the functioning of the entire network in a negative way. Similarly, DoS attack may be possible also for the switches in the data plane. The flow tables of the switches which have limited cache will be vulnerable to flooding attacks when the attackers send large packets which belong to different flows. As previously stated, some of the flow rules are not available in the flow table so the queries are sent to the controller. While waiting the answer to these queries, the cache of the switches will fill up quickly. This type of attack is also called as DoS Switch [5].
Controller hijacking or unauthorized controller access attacks target the confidentiality principle of the security. Vulnerabilities in the controller may have consequences which can put the entire network at danger [3]. The attacker can take over the management of misconfigured, vulnerable controller and also the management of the network. Then, the attacker can programme switches in the data plane to drop the traffic coming to the controller can use to launch attacks on other targets [5].

In the absence of mechanisms to ensure security in the communication between the control plane and the application plane, malicious applications can insert fraudulent rules into the flow table of switches. This will cause the conflict rules in the network. Therefore, reliable connection must be established by creating authorization and authentication mechanisms between controllers and applications [4].

Man-in-the-middle (MITM) attack, which occurs between control plane and the data plane communication targets confidentiality and integrity principle of security. Both the control plane and data plane will be affected by this attack type. The data modification between the control plane and the data plane is one of the most important problems in SDN. SDN architecture brings discrete planes and using unencrypted protocols in the communication between these discrete planes can cause serious consequences. MITM attack, which performs in the second layer of the OSI reference model, allows eavesdropping or modifying the traffic flow between network resources such as server, router or switch and endpoint on the network. In this case, the attacker may modify flows on the switches or be able to add new flow rules [4]. Communication channel can be made more secure by the use of TLS which is a cryptographic protocol [6]. OpenFlow protocol supports TLS connection by default. Mutual authentication can be done by exchanging certificates between controllers and switches which are responsible for the transmission of network packets. The attacker cannot view or modify the contents of messages when encrypted protocols are used. However, TLS/SSL and Public Key Infrastructure (PKI) has some weaknesses and these vulnerabilities could be exploited [7]. If an attacker can access control plane by benefiting the protocol vulnerabilities in communication, switches under its control can be used to launch DDoS attacks [3].

Unauthorized and unauthenticated applications target confidentiality and integrity principle of the security. There are many third-party applications which run at the application layer. Controller provides abstraction for the SDN applications and this enables the applications to read and write network state [4]. This situation poses a problem for the control of the network. The attacker can use the applications that cause unauthorized access to hide himself and access network resources and manipulate the operation of the network [4].

<table>
<thead>
<tr>
<th>Attack Surface</th>
<th>Attack Type</th>
<th>Attack Definition</th>
<th>Attack against Security</th>
</tr>
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<tbody>
<tr>
<td>Application Plane</td>
<td>Interception, Modification</td>
<td>Unauthorized/Unauthenticated Applications</td>
<td>Confidentiality, Integrity</td>
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<tr>
<td>Application-Control Interface</td>
<td>Fabrication</td>
<td>Fraudulent Rule Insertion</td>
<td>Integrity</td>
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<tr>
<td>Control Plane</td>
<td>Interruption</td>
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<td>Availability</td>
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<td>Interception</td>
<td>Controller Hijacking, Unauthorized Controller Access</td>
<td>Confidentiality</td>
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<tr>
<td>Control-Data Interface</td>
<td>Interception, Modification</td>
<td>Man-in-the-Middle</td>
<td>Confidentiality, Integrity</td>
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<td>Data Plane</td>
<td>Interruption</td>
<td>Flow Table Flooding</td>
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Administrative computers that are directly connected to the controller can cause an entry point into the network. If these computers have some vulnerability the attacker can use these vulnerabilities to get control of the computers to access the controller easily.

Additionally, not quickly detecting an error or a problem in the network and a failure to obtain a reliable recovery point of the network is considered as a threat vector [3].

IV. SDN SECURITY SOLUTIONS

There are some comprehensive surveys [4], [8]-[11] on SDN and SDN security. In these papers, concept, architecture, core components, advantages, current challenges of SDN and SDN specific security threats and solutions are discussed in detail.

Despite the advantages provided by SDN architecture, it is necessary to review network security issues. In this context, there have been some studies carried out in literature. In these studies, prevention and mitigation of DoS and DDoS attacks are mainly considered. Furthermore there are also the studies on authentication and authorization mechanisms, development of network security applications such as IDS/IPS and firewall. In this section, some of these studies on SDN security are described.

Some security measures are offered in [3] where also SDN-specific threat vectors are discussed. In case if only one controller is used and the controller is collapsed, there will not be a fault tolerance of the network and whole network may have collapsed which is called Single Point of Failure (SPOF). To avoid this situation creation of replication of controllers and applications is proposed. Against software bugs usage of diversity of controllers is recommended. Furthermore, it is stated that the switches in data plane must be able to keep in touch with another controller in case the controller is collapsed. In such a case, dynamic device association mechanism which provides the connection of switches with multiple controllers dynamically would tolerate the faults in the network.

Use of OpenFlow protocol leads to some security issues with it. For example, an attacker may send too many OpenFlow request and expose the control plane to DoS attack. This case will cause a bottleneck between control plane and data plane. So, the network will be unmanageable. Therefore, the central controller must be protected from DoS and DDoS attacks which can affect the entire network. A framework which is called AVANT-GUARD [12] has been developed for the purpose of enhancing security in OpenFlow networks. This framework is located in the data plane and consists of two modules named Connection Migration and Actuating Trigger. Intelligence is added to the data plane in Connection Migration and control plane is being more resistant against DoS attacks such as TCP SYN. This is carried out by analyzing the TCP sessions opened in the data plane. Connection Migration module decreases the interaction between control plane and data plane. The Actuating Trigger module provides the installation of the necessary flow rules. It is stated that this plug-in is also effective against network scanning attacks but does not provide any protection against DoS attacks in application-level and UDP or ICMP protocols-based attacks. It is expressed that after the attack is detected, control plane should be able to respond quickly. Therefore, quick access to the statistics belonging network traffic from data plane is of great importance. Within the scope of study, the statistics are collected from data plane and sent to the control plane. Accordingly, the behaviors detected as attack are prevented.

IDS and Anomaly Detection System (ADS) are used for the purpose of providing protection against threats in traditional network infrastructures. These security systems are generally located in Internet Service Providers (ISP) or backbone devices. This approach changes in SDN. These systems can be brought to the endpoints with SDN. In a study [13], ADS is proposed for home and Small Office/Home Office (SOHO) networks using OpenFlow. Accordingly, an application which runs in NOX [14] controller is developed and implementation of four anomaly detection algorithms are showed. This solution offers more efficient anomaly detection in home and SOHO networks than the ISP.

In another study [15], usage of central controller is proposed for the detection of DDoS attacks. Random distribution of incoming packets to the network is calculated in this method that runs on POX [16] controller. Entropy is used in order to calculate this probability. There are two components in DDoS detection. One of them is windows size and the other one is threshold. The window size is depended on time period and number of packets. Entropy calculates random distribution of incoming packet depending on window size. If the entropy value exceeds the predefined threshold value, traffic is determined as an attack. The proposed method can detect the attack within the first 250 packets of harmful traffic by using destination IP addresses. It is stated that attack detection rate for the predefined threshold value is %96. Furthermore, such parameters as destination IP addresses, window size and threshold value can be set to the desired values in real time according to the requirements of the controller. In this respect, it offers a flexible solution. Also, tests are performed and same results are obtained for TCP and UDP packets. It is stated that detecting DDoS in its early stages is depended on tolerance of the server used as a controller and traffic properties.

In a recent work [17], a simple DoS prevention system is performed in SDN. A solution is offered against DNS DoS attacks using flow information obtained from each network device. Therefore, anomaly detection can be performed on each switch in the local area network. Also, the advantage of central management which is brought by SDN architecture is discussed.
Controller acts like a firewall in OpenFlow-based networks. The traffic is passed on the controller and analyzed. According to its result, passing of packets is allowed or rejected. In [18], it is discussed that a design acts like a firewall of each switch in data plane and sending of packets to the controller is not necessary. A flow-based distributed firewall prototype is developed in this work for developing a simple packet filtering firewall in SDN. The rule set is installed on each network device as flow entries. This firewall prototype creates a firewall object for each network device connected to the controller. Firewall object is connected to the related device without any delay. Each firewall object has an index number and stored in a list in order. The functions of each firewall object can be accessed through command line by index number in the list. Firewall can control the traffic by modifying flow tables of switches in data plane.

In [19], more than one controller usage is suggested for the purpose of protecting control plane from unauthorized access in SDN. Each switch in data plane can be managed by more than one controller using byzantine fault tolerance algorithm.

A security application kernel which is called FortNOX [20] is proposed for preventing fraudulent rule insertion that may be caused by malicious applications. FortNOX provides prioritizing the flow rules by performing role-based authorization. Furthermore, it detects a new flow rule which conflicts with an existing flow rule.

Security Enhanced Floodlight (SE-Floodlight) which is an extension of OpenFlow controller Floodlight is introduced in [21]. SE-Floodlight which is an improvement of FortNOX offers a Security Enforcement Kernel (SEK). It provides role-based authorization between control plane and OpenFlow applications in application plane. SE-Floodlight has a digital signature validation for each rule insertion. OpenFlow application is digitally verified by the SEK at runtime. After the application is signed and validity is verified, it is permitted for the purpose of making query, modification on the network or creating traffic flow rule.

In [22], assignments of full privileges for each OpenFlow application which cause unauthorized access problems are discussed. In this context, an isolation mechanism is proposed. The system which is called PermOF provides permissions with minimum privileges for applications. PermOF enforces to perform these permissions in Application Programming Interface (API) entry of the controller. It is stated that this solution protects the network from unauthorized controller attacks.

In [23], a solution which is called Virtual Address Validation Edge (VAVE) is proposed for IP spoofing in OpenFlow/NOX architecture. VAVE is an application that runs on the controller. It performs source address validation against IP spoofing attacks. If any incoming packet does not match a rule in the flow table of OpenFlow switch then first packet is sent to the NOX controller for source address validation. If an IP spoofing is detected then controller adds a rule to the switch in order to stop incoming traffic from this source address. VAVE provides protection against data plane DoS attacks such as flow table flooding.

OpenFlow and sFlow is combined for anomaly detection and mitigation in [24]. This solution consists of collector, anomaly detection and anomaly mitigation modules. Flow statistics are gathered by using OpenFlow and sFlow protocols in the collector module. The statistics are analyzed and anomalies are identified in anomaly detection module. Flow-entries are inserted in the flow table of switches in order to neutralize malicious traffic in anomaly mitigation module. Flow-entries which are inserted have higher priority than any existing flow-entry in the flow table. These modules act as a feedback control loop. This architecture supports various algorithms such as statistical anomaly detection, machine learning-based anomaly detection and data mining-based anomaly detection according to preferred design. In this study, entropy-based algorithm is used. DDoS attacks, worm propagation and port scan attacks are detected successfully.

SDN, Network Functions Virtualization (NFV) and cloud computing technologies will play important role to meet the requirements of future mobile networks. In [25], multi-tier security architecture is presented to solve the security problems in the future of Software-Defined Mobile Networks (SDMN). This architecture consists of four components. Security is provided between the control and data plane communication by using Host Identity Protocol (HIP) and IPSec tunneling techniques. Rule-based approach is used to protect the network to unwanted access, source address spoofing and DoS attacks. Software-Defined Monitoring (SDM) is used to detect and prevent security threats on the network. SDM uses Deep Packet Inspection (DPI) and traffic monitoring techniques. Synchronizing network security with the network traffic provides real-time information and necessary flow rules are installed to the flow tables of switches in the data plane.

V. CONCLUSION AND FUTURE WORK

SDN bring a new generation networking approach. Traditional and cumbersome network architectures transform into the dynamic network architecture with SDN. Although SDN provides an open and programmable platform there are many problems to be solved in topics such as network security, routing algorithms, virtualization and load balancing. SDN must be designed in a good manner from the security perspective.

At this stage, we believe it is too early that we can say SDN provide a secure network infrastructure. There is much work needs to be done and more effort should be spent on SDN security for SDN potential.
Cognitive Networks (CN) which exhibit intelligent behaviours will probably come out in the near future, we believe AI-based solutions in SDN security would be much more useful. Studies on integration of AI techniques with SDN, 4G/5G networks, Heterogeneous Networks (HetNets) and mobile networks can play an important role in the creation of CN. Processing big data with using AI techniques such as machine learning will allow the development of CN. CN will depend on information and be learning-based, exhibiting intelligent behaviors. With CN, it may be possible to develop networks which can learn from past data and decide automatically about encountered in future events. It will be possible to give specific services to the users with this intelligent network architecture. As a future work, we plan to represent these issues and propose new solutions in the following publications.

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Segmentation Process on Videocapillaroscopic Images by Matched Filter

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Keywords—Görüntü bölültüleme, Kapiller video, Segmentasyon, Matched filter

I. INTRODUCTION


Videocapillaroscopic Bölütlenme Algoritması

Videocapillaroscopic görüntüsi

Görüntünün birinci kanalını

Parlak Bölgeleri

Önerilen Algoritmalar (Eşleştirilmiş filtre)

Optimum Parametrelerin Bulunması ve Uygulanması

Morfologikal yöntemleri kullanarak

Damarlar bölüldendi

Şekil 1. Önerilen yöntemin akış diyagramı

Aşağıda eşleşme yöntemi uygulayarak sonuçlar elde edilmiştir. Sonuçlar göre threshold (eşleşme yöntemi) çok iyi bir sonuç vermemiştir. Mesela aşağıdaki sonuç 130 ve 150 için elde edilmiştir. Bazı bölgeler damar olarak yanlış bulunuyor ve bazı damarlar yanlış olarak damar bulunmamıştır.

Bu çalışmada bulunamayan ve yanlış bulunan bölgeleri iyileştirmeye çalışılmıştır.

Bu bölgeler aşağıdaki şekilde gösterilmiştir.

Şekil 2. Eşleşme yöntemi kullanarak elde edilen sonuçlar, sağdaki sonuç 130 için ve soldaki sonuç 150 için.

Bu çalışmadan bulunamayan ve yanlış bulununun bölgeleri iyileştirmeye çalışılmıştır.

Bu bölgeler aşağıdaki şekilde gösterilmiştir.


Algoritma değerlendirme parametreleri

TP (Doğru Pozitif): Algoritmanın damarlara ait olduğunu tespit ettiği piksel sayısını gösterir. Bu pikseller damarlara bulunmaktadır.

FP (Yanlış Pozitif): Algoritmanın damarlara ait olduğu tespit ettiği piksel sayısını gösterir fakat aslında damarlarda mevcut değildir.

TN (Doğru Negatif): Algoritmanın damarlarda bulunmadığını tespit ettiği piksel sayısını gösterir; gerçekte de bu pikseller damarın bir parçası değildir.

FN (Yanlış Negatif): Algoritmanın arka plana ait olduğunu tespit ettiği piksel sayısını gösterir fakat bu pikseller damarlara aittır.

Şekil 4'te, söz konusu parametreler kısaca gösterilmiştir.

Şekil 4. TPR ve FPR örneklemeleri; TP, doğru biçimde pozitif olarak etiketlenen pozitif pikselleri gösterir; FP, pozitif olarak etiketlenen negatif pikselleri gösterir; FN, yanlışlıkla negatif olarak etiketlenen pozitif pikselleri gösterir ve TN, doğrulan biçimde negatif olarak etiketlenen negatif pikselleri gösterir.

TPR ve FNR, sırasıyla, damarla ait olan toplam piksel sayısına göre doğru pozitif oran kriterini ve yanlış negatif oran kriterini verir. FPR ve TNR, sırasıyla, damarlara ait olmayan toplam piksel sayısına göre yanlış pozitif kriter ve doğru negatif kriter oranını verir. Bölgesel tanımlarla ilgili olarak, algoritma doğruluğu denklem (3)'deki gibi açıklanır.

\[
Acc = \frac{TP+TN}{TP+FN+TN+FP}
\]

(3)
Bahsedilen kriterlere ek olarak, “Hassaslık” olarak adlandırılan diğer bir görüntü sınıflandırma kriteri vardır ve denklemi şu şekildedir;

\[
Sensitivity = \frac{TP}{TP+FN}
\]  

(4)

REFERENCES


The Detection of Gastric Cancer With Semi-Automatic Image Processing Techniques
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Abstract— Gastric cancer is one of the most common and the most common fatal cancers in the world. In this study, our aims to detect the cancerous regions semi-automatically according to the endoscopy images obtained. In this process, semi-automatic diagnosis of cancer is done according to the endoscopic images received from the patients using image processing techniques and the results are compared with the cancerous region determined from the endoscopic images by specialized doctors. The Gastric cancerous region obtained semi automatically using image processing techniques and determined by the specialized doctors are compared. 96.1641% accuracy rate is determined from the comparison results. Considering the results obtained, it can be seen that the suspected region can be determined via software by the specialized doctors.

Keywords— Gastric Cancer, Image Processing, Endoscopic Image

I. INTRODUCTION
Gastric cancer is the fourth most commonly diagnosed cancer and the second leading cause of cancer-related deaths worldwide [1]. Symptoms associated with gastric cancer often seen in advanced stage tumors. Therefore, it is not easy to diagnose the tumors at an early stage of the cancer. Endoscopic examination and biopsy is the most important tool in the diagnosis of the gastric cancer. In the examination, all parts of the gastric can be seen and the cardia and fundus evaluation can be provided. The accuracy rate of diagnosis by biopsy is around 80% - 85% [2]. The detection of cancerous regions using image processing techniques is aimed by benefitting from endoscopy images obtained from the patients in the Selcuk University Medical Faculty Hospital Gastroenterology Unit. Endoscopic images generally contain elements that are unsuited or irrelevant for our analysis. For example, specular reflections and intestinal juices cover the surface tissue with color and texture patterns, rendering these image parts unsuited for cancer detection based on color and texture analysis. The black image border and the lumen do not show any tissue, which makes them irrelevant for our detection system. Since we aim to use color and texture information for the detection of early cancer, we define a region of interest for two reasons: (1) decreasing the number of false positives that are caused by other texture-rich or color-deviating parts of the image and (2) reducing the computation time by only analyzing the relevant image area[3].

II. MATERIAL VE METOTLAR
In this study, image processing techniques and Image Processing Toolbox of Matlab R2016a has been used for this study.

2.1. Digital Image Processing:
Image processing is a rapidly growing area of computer science. Its growth has been fueled by technological advances in digital imaging, computer processors and mass storage devices. Fields which traditionally used analog imaging are now switching to digital systems, for their flexibility and affordability. Important examples are medicine, film and video production, photography, remote sensing, and security monitoring. These and other sources produce huge volumes of digital image data every day, more than could ever be examined manually [4].

The comparison between semi-automatically detected cancerous region and the detected region by specialized doctors is done in this article.

In computer vision, image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels, also known as super-pixels). The goal of segmentation is to simplify and/or change the representation of an image into
something that is more meaningful and easier to analyze.[5][6] Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics.

In one kind of segmentation, the user outlines the region of interest with the mouse clicks and algorithms are applied so that the path that best fits the edge of the image is shown.

Techniques like SIOX, Livewire, Intelligent Scissors or IT-SNAPS are used in this kind of segmentation. In an alternative kind of semi-automatic segmentation, the algorithms return a spatial-taxon (i.e. foreground, object-group, object or object-part) selected by the user or designated via prior probabilities[7][8].

2.2. Implementation of Semi-Automatic Image Processing Techniques to the Image Captured From Endoscopy

In this section, the image processing software is implemented to the endoscopy image captured in Selcuk University Faculty of Medicine, Gastroenterology Unit.

The endoscopy image taken from the patient is shown in Fig.1.

Fig1

In this application, it is required for the doctor to click on the image to determine the predicted cancerous region due to the application being semi-automatic. Afterwards, the software calculates the accuracy rate by comparing the regions determined by the specialized doctor and determined by using image processing techniques.

III. RESULT AND DISCUSSION

When the software is executed, it starts the segmentation process on the endoscopy image. Fig.2 below shows the field scanning system applied on the image. This system is created based on the method which combines the discrete areas.

Fig2

The representation of images, which is the combination of discrete areas, applied on the endoscopy image is shown in Fig.3.
At this stage, after the segmentation process, the specialized doctor activates the software by clicking on the suspected cancerous regions. During the execution of the software, the region determined after the segmentation process and the region determined by the specialized doctor is compared and the accuracy rate is calculated.

The cancerous region determined by the software is shown in Fig. 4.

On the other hand, the region determined as cancerous by the specialized doctor is shown in Fig. 5.

IV. CONCLUSIONS

In this study, success is obtained in the semi-automatic detection of gastric cancer with image processing techniques. In our study, values such as accuracy rate of 96.1641% and 0.8160 Area Under Curve (AUC) value indicates our success rate. Roc Analysis chart belonging to AUC is shown in Fig.6.

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V. REFERENCES


Decision Tree Application for Renal Calculi Diagnosis

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Abstract—Data mining is used for the extraction of secret, valuable and usable data from the big data and to provide strategic decision support. It created a new perspective for the use of the data in healthcare in addition to finding the answers of unexplored questions. It has gained wider usage as a method. The aim of this study is to develop a decision tree and a list of rules by data mining for the early diagnosis of renal calculi. A data set including blind and retrospective data for 150 people can diagnose with 6 attributes. A decision support system analysis was developed for the diagnosis of the patients with suspected renal calculi. Based on the results obtained and the analysis developed, a decision tree and list of rules were created to determine the factors that affect renal calculi. Weka program and J48 algorithm were used to create the decision tree and the list of rules and it was found to be 74.63% successful.

Keywords—Data Mining, Decision Tree, Renal Calculi Diagnosis, J48

I. INTRODUCTION

The aim of medical informatics is to use computer and communication technologies that are interacting with other sciences in order to utilize, analyze and reconstruct medical information in an effective way. Medical informatics helps to obtain valid, detailed and reliable results on a global scale as it exponentially improves the data collection, process and evaluation capacities in medical centers [1].

A renal calculus is among the most common diseases in Turkey. About 15% of women and 5% of men in Turkey have been diagnosed with nephrolithiasis. It generally occurs in thirties for the first time. Kidneys are like filters in the human body and they help the disposal of waste through the urinary tract. Sometimes some of this waste might cumulate in the kidneys. Renal calculi are the solid pieces that are formed with the crystallization of calcium, phosphate and other minerals in the urine.

Drinking inadequate amount of water, obesity, consuming too much sugar and salt might cause nephrolithiasis as well as genetic factors. Most of the renal calculi are calcium stones resulting from the accumulation of the calcium in the kidneys.

In addition to the environmental factors in the formation of renal calculi, genetic factors may be the primary cause. Not having enough water is one of the biggest risk factors for renal calculi. It is often recommended to drink about 2 liters of water daily. Besides, it is good for our well-being in general not to consume too much sugar and salt, to follow a balanced diet, to stay away from convenience food and not to be overweight. Renal calculi may also stay in the kidneys without showing any symptoms or doing any harm to the kidneys. Following the general information given for renal calculi, we are going to talk about data mining.

Data mining is the extraction of secret, valuable and usable information from a big amount of data. Data mining which is used to provide strategical decision support aims to construct decision making models based on analysis methods.

It creates directive models for decision making techniques for medical institutions where the data is collected for analyses [2]. It is important to emphasize the difference between flaws and misappropriations in health services, to minimize the risks and to take necessary precautions based on
this distinction for patients’ security and well-being [3] [4]. A large amount of information can be retrieved from the various data sets used in daily life [5, 6]. Data mining has made life easier by enabling us to access to more data in a shorter time span [7]. In the simplest term, data mining is the extraction of imprecise, valid and applicable data from data stacks with a dynamic process [8, 9]. It is possible to obtain valuable information from the big data stacks using data mining and statistical analysis techniques. This information helps doctors during the decision process with computer-aided diagnosis work and contributes to the improvement of health care applications [10].

Although potent devices have been produced by expert systems, they have not gained common use because of the field-related data changing rapidly and the diversity of views among experts [11]. Data warehouse is a large store of data accumulated from a wide range of sources under the same roof [12]. The steps in data mining include the definition of the problem to be solved, the obtaining of previous data about the problem, the selection of usable data, housekeeping of the data, the evaluation of analysis results, and the utilization of these results [13, 14]. The time saving and accelerating effect of the data selection will be obvious in the later stages [15].

A decision tree is an approach commonly used in data mining for categorization and estimations. Decision trees benefit the decision makers as they are easy to interpret and understand [16, 17].

C5.0 Algorithm

It is one of the most common decision tree algorithms, especially used for big data sets. C5.0 helps us to get more proper decision trees in terms of form [18]. WEKA is an open coded data mining program with a functional graphics interface which keeps machine learning algorithms together [19, 20].

II. RECENT STUDIES

İlkuçar examined the chronic kidney disease with the help of artificial neural networks in his study. He emphasized what is to be done and which tests to be run for early diagnosis of chronic kidney disease [21]. Danacı et al. focused on the diagnosis of breast cancer cells using data mining methods [22]. In the study conducted by Yurtay et al. they did a data mining research for anaemia diagnosis. In a study on iron deficiency anaemia, the system is run with decision trees [23]. Özkan et al. tried to improve the diagnosis accuracy of the laboratory tests used for the diagnosis of fibromyalgia syndrome which are supported by sympathetic dermal response parameters. SSR parameters and laboratory tests which were calculated by Matlab were analyzed with artificial neural networks and the percentages of accuracy were found [24]. Kökver et al. probed the factors affecting hypertension with data mining methods. They developed a diagnosis system that will estimate whether the patients have hypertension or not [25].

Kusia et al. work through a decision support system which will determine whether the lung tumor is benign or malignant [26]. In their research, Topaloğlu & Sur created a decision support system to diagnose hepatitis and to minimize the number of wrong diagnoses. It will help the doctors with the diagnosis of hepatitis [27].

III. MATERIALS AND METHODS

The Aim of the Study

The aim of the study is to make the diagnosis of renal calculi easier and help doctors with the process. A decision tree and list of rules were created based on the full urinary tests for the diagnosis of the disease. It is possible to avoid misdiagnoses with the decision tree and the list of rules based on facts. Patients can benefit from early diagnosis of a disease they have.

Weka program was utilized for the design of the list of rules and the decision tree. The values of the patients were categorized and the roots and the branches of the decision tree were determined.
The Importance of the Study

Urinary analysis is one of the most common methods used for the diagnosis of renal calculi. Especially substances like uric acid and calcium present in normal urine become crystallized and form the structures called renal calculi. These formations can have great negative effects on a patient’s daily life. The diagnosis of the disease of which treatment process is quite hard is also of utmost importance.

Data Set

For this study, a data set including retrospective and blind data from 150 people. Six attributes were used for the diagnosis of the disease. The seventh attribute is the comments “yes” and “no” for the diagnosis. The six attributes used are as follows;
- Leucocyte
- Urine color
- PH
- Bilirubin
- Appearance
- Erythrocyte.

The Decision Tree Model and Algorithm to Be Applied to the Data Set

A decision tree and a list of rules were formed with the Weka program used in the study. Before that, the data set was processed in csv format and the data was converted to arff format and transferred to Weka Program. J48 algorithm was used to determine the factors contributing to the formation of renal calculi and for the diagnosis. RISK was selected as the root node. The results were transferred with the decision tree and the list of rules.

IV. FINDINGS

Full urine analysis can provide us with very important information of the presence of kidney problems and activities. After the full urine analyses that make up the data set were categorized, they were transferred to Excel program. The file was saved in csv format for WEKA program.

The Formation of the Decision Tree with Weka

J48, which is a decision tree algorithm, was used in the program. The last one of the training set with seven attributes is the “RISK” attribute where the diagnosis is made. The others are as follows; Leucocyte (LOW, MILD, HIGH), Urine Color (COLORLESS, STRAW-COLORED, YELLOW), PH (LOW, NORMAL, HIGH), Bilirubin (NEGATIVE, POZITIVE), Appearance (CLEAR, BLURRED, SLIGHTLYBLURRED, HEAVILYBLURRE), Erythrocyte (TRACE AMOUNT, RARE, NORMAL). 55% of the data obtained were used for training while the rest was used for testing. Classification model provides information about the structure and the size of the tree. This model belongs to the learning set.

Full Urine Analysis and Value Ranges

If Leucocyte value is between; 0 and 3 \(\rightarrow\) Low, 3 and 5 \(\rightarrow\) Mild, 5 and above \(\rightarrow\) High
If PH value is between; 4,5 and 5,5 \(\rightarrow\) Low, 5,5 and 6,5 \(\rightarrow\) Normal, 6,5 and 7,5 \(\rightarrow\) High.
If Erythrocyte value is between; 0 and 4 \(\rightarrow\) Rare, 4 and 9 \(\rightarrow\) Normal, 10 and above \(\rightarrow\) Trace Amount

The relation and attribute expressions of the arff file is shown below;
@relation kidney disease
@attribute LEUCOCYTE string
@attribute COLOR string
@attribute PH string
@attribute BILIRUBIN string
@attribute APPEARANCE string
@attribute ERYTHROCYTE string
@attribute DISEASE string
@Data

The number of the leaves is 7 while the size of the tree is 10.
Evaluation module gives the classification error and the Kappa (=0.482) statistic both. The mean absolute error and the root mean squared error of the category probability estimations assigned by the tree are found 0.3049 and 0.4345, respectively. Classification performance was calculated as 74.63%. This value shows that the decision tree is 74.63% successful.

The algorithm excludes meaningless variables automatically and it makes the selection of the variables itself during the new learning process [28]. Here, the gender was considered to be a meaningless variable and it was excluded from the decision tree variable order. Activity was chosen as the root node. The decision tree created based on J48 algorithm is presented in Figure-1.

The list of rules based on the decision tree created by J48 algorithm is as follows:

1. If ERYTHROCYTE = Trace amount, then Risk = Yes
2. If ERYTHROCYTE = Rare, then Risk = No
3. If ERYTHROCYTE = Normal and Color = Colorless, then Risk = Yes
4. If ERYTHROCYTE = Normal and Color = Yellow, then Risk = No
5. If ERITROSIT = Normal and Color = Straw-colored and LEUCOCYTE = Low, then Risk = No
6. If ERITROSIT = Normal and Color = Straw-colored and LEUCOCYTE = High, then Risk = Yes
7. If ERITROSIT = Normal and Color = Straw-colored and LEUCOCYTE = Medium, then Risk = Yes

V. CONCLUSIONS

Full urine analysis values were examined with the method used in this study. It is possible to diagnose renal calculi without a surgical examination of the patient. Thus, it helps to take the necessary precautions for nephrolithiasis.

According to the design of the decision tree, the most important attribute to take into account is the amount of Erythrocyte. If the amount of the Erythrocyte is above 10, then a pathological test needs to be done with ultrasonography. Again, if the amount of the Erythrocyte is between 4 and 9, then the color of the urine, which is among the attributes, should be examined. If the color is “Yellow”, it means that you do not have any renal calculi. If the color is “Straw-yellow”, then the amount of the Leucocyte should be examined. If the amount of Leucocyte is more than 3, then you are very likely to have renal calculi. If it is below 3, then you do not have it. If the color of the urine is “Colorless”, then you need to have and pathological test. If the amount of the Erythrocyte is below 4, it means that you are less likely to have kidney problems.

The application we designed using data mining methods would help the diagnosis and treatment processes in medicine. It would be very beneficial for biological/medical fields, both clinically and executively, to get help from data mining. It is important to use the results in a safe way in every stage of diagnosis and treatment processes. The aim is to use the decision tree results through the data mining application based on the results obtained. Besides, the first step towards the formation of decision support system was taken with the list of rules created.

REFERENCES


Classification of Genuine and Counterfeit Banknotes by Using Data Mining Algorithms

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Abstract— In this study, the banknote authentication data set in the UCI machine learning repository was used as classification data set. Four features obtained from banknote images that were taken from genuine and counterfeit banknotes were used for classifying them as genuine or counterfeit. 906 of 1372 data in the dataset were assigned for training and rest of them were assigned for testing. Weka (Waikato Environment for Knowledge Analysis) software was used as classification environment. The classification success rates were calculated by using data mining algorithms like Multilayer Perceptron, RBFNetwork, RBFClassifier, kNN, J48, RandomForest, RandomTree, NaiveBayes, BayesNet, OneR, DecisionTable and Kstar. The best classification success rate was achieved by using Multilayer Perceptron model. The classification success rates for various number of neurons in the hidden layer were obtained in Multilayer Perceptron model. The best success rate was obtained as 100% when the model has 4 neuron in the hidden layer.

Keywords— Data mining, Weka, MLP, kNN

I. INTRODUCTION

By the improvement in banking services the Asynchronous Transfer Mode (ATM) machines have been grown up worldwide. Due to this fact the classification of banknotes as genuine or counterfeit become an important issue. Image processing occupies an important role during feature extraction. After the feature extraction operation data mining algorithms have to be used for classification.

Shan et al. (2013) used quaternion wavelet transform for feature extraction. In their study, Artificial Neural Network (ANN) has been used as classifier. The lowest classification error rate is determined as 0.58%. Ali et al. (2004) have proposed a method that rejects counterfeit banknotes. The improvement of reliability in banknote neuro-classifier is investigated and a reject option is proposed based on the probability density function of the input data. In their study, for modelling the non-linear correlation among the data variables and extracting the features, a local principal components analysis (PCA) is applied. The method is tested with a learning vector quantization (LVQ) classifier. The results show that by taking a suitable reject threshold value and also a proper number of regions for the local PCA, the reliability of system can be improved significantly. Esra et al. (2015) has performed clustering process using ANN approach on the pictures belonging to our dataset to determine if the banknotes are genuine or counterfeit. Four input parameters, one hidden layer with 10 neurons and one output has been used for the ANN. Wavelet Transform tool are used to extract features from images. It is determined that the training regression is 0.99914, testing regression is 0.99786 and the validation regression is 0.9953, respectively. Mariana et al. (2013) have used Raman spectroscopy and Partial least squares discriminant analysis (PLS-DA) for determining the authentic and counterfeit banknotes. The classification method PLS-DA is employed to discriminate authentic and counterfeit banknotes, as well as the counterfeit type. In the proposed method all fake and not fake banknotes used to validate the analysis are correctly classified. Hinwood et al. (2006) have designed a system that helps the blind Australians to recognition of banknotes. Each note has the same feel, with no Braille markings, irregular edges or other tangible features in Australia. Their portable system called MoneyTalker scans and speaks about the banknote. The accuracy, weighted by the percentage breakdown of total notes in issue is determined as 98.9%.

In this study the banknotes have been classified as genuine or counterfeit by using 4 attributes created from their images that obtained from banknote authentication dataset. In classification process 12 machine learning algorithm have been used. The classification success rates and error values obtained from each classification algorithm have been compared.

II. MATERIAL AND METHODS

Dataset

In this study, images that were taken from genuine and counterfeit banknote-like specimens have been used to extract four attributes. For digitization, an industrial camera usually used for print inspection, was used. The final images have 400x400 pixels. Due to the object lens and distance to the investigated object gray-scale pictures with a resolution of about 660 dpi were gained. Wavelet Transform tool were used to extract features from images. The attributes that have were
variance of Wavelet Transformed image, skewness of Wavelet Transformed image, curtosis of Wavelet Transformed image and entropy of image. The data set was obtained from UCI machine learning repository [6].

Software-WEKA

Developed by Waikato University in New Zealand, WEKA is an open-source data mining software with a functional graphical interface which incorporates machine learning algorithms [7]. WEKA includes various data pre-processing, classification, regression, clustering, association rules, and visualization tools. The algorithms can be applied on the data cluster either directly or by calling via Java code [8][9]. They are also suitable for developing new machine learning algorithms.

Machine Learning Algorithms

It is a feed forward type artificial neural network model which maps input sets onto appropriate output sets. A multilayer perceptron (MLP) is composed of multiple layers of nodes where each layer is connected to the next. Each node is a processing element or a neuron that has a nonlinear activation function except the input nodes. It uses a supervised learning technique named back propagation and it is used for training the network. The alteration of the standard linear perceptron, MLP is capable of distinguishing data which are not linearly separable [9]

For classification of banknotes as genuine or counterfeit MLP model have been executed by using 4 attributes that obtained from those pictures. By using same data set RBFNetwork, RBFClassifier, kNN, J48, RandomForest, RandomTree, NaiveBayes, Bayesnet, OneR, DecisionTable and Kstar machine learning algorithms have been proposed for classification. The block diagram of the classification process is seen in Figure 1.

III. RESULTS AND DISCUSSION

During classification process the WEKA software have been used for application of algorithms. Classification success rates and error values like MAE and RMSE have been determined by changing the neuron numbers in the hidden layers in the classification by using same dataset on MLP model. The success rates, MAE and RMSE values have been presented on Table 1. The highest success rate have been obtained when the number of neuron in the hidden layer is 4 for MLP model. The MLP model for best situation has been presented in Figure 2.

<table>
<thead>
<tr>
<th>The number of neurons in the hidden layer</th>
<th>Classification Success (%)</th>
<th>MAE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>98.927</td>
<td>0.0204</td>
<td>0.0836</td>
</tr>
<tr>
<td>2</td>
<td>99.7854</td>
<td>0.0115</td>
<td>0.0503</td>
</tr>
<tr>
<td>3</td>
<td>99.5708</td>
<td>0.0065</td>
<td>0.0479</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
<td>0.0036</td>
<td>0.0115</td>
</tr>
</tbody>
</table>

Then the same data set have been used for classification with the RBFNetwork, RBFClassifier, kNN, J48, RandomForest, RandomTree, NaiveBayes, BayesNet, OneR, DecisionTable and Kstar machine learning algorithms. The classification success rates, MAE and RMSE error values for these algorithms have been obtained. The success and error rates obtained using 11 different classification algorithms (Multilayer Perceptron, kNN, RBFNetwork, RBFClassifier, kNN, J48, RandomForest, RandomTree, NaiveBayes,
BayesNet, OneR, DecisionTable and Kstar) can be seen in Table 2. The diagram demonstrating the error values obtained based on different machine learning algorithms have been presented in Figure 3.

### Table III

<table>
<thead>
<tr>
<th>Machine learning algorithms</th>
<th>Classification Success (%)</th>
<th>MAE</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multilayer Perceptron</td>
<td>100</td>
<td>0.0036</td>
<td>0.0115</td>
</tr>
<tr>
<td>RBFNetwork</td>
<td>94.4206</td>
<td>0.0665</td>
<td>0.192</td>
</tr>
<tr>
<td>RBFCclassifier</td>
<td>99.5708</td>
<td>0.07</td>
<td>0.115</td>
</tr>
<tr>
<td>kNN</td>
<td>99.5708</td>
<td>0.0054</td>
<td>0.0654</td>
</tr>
<tr>
<td>J48</td>
<td>96.3519</td>
<td>0.0389</td>
<td>0.1801</td>
</tr>
<tr>
<td>RandomForest</td>
<td>98.927</td>
<td>0.0227</td>
<td>0.0903</td>
</tr>
<tr>
<td>RandomTree</td>
<td>97.2103</td>
<td>0.0279</td>
<td>0.167</td>
</tr>
<tr>
<td>Naive Bayes</td>
<td>85.6223</td>
<td>0.1842</td>
<td>0.3158</td>
</tr>
<tr>
<td>Bayesnet</td>
<td>93.3476</td>
<td>0.1272</td>
<td>0.2422</td>
</tr>
<tr>
<td>OneR</td>
<td>85.8369</td>
<td>0.1416</td>
<td>0.3763</td>
</tr>
<tr>
<td>DecisionTable</td>
<td>95.279</td>
<td>0.0898</td>
<td>0.1869</td>
</tr>
<tr>
<td>Kstar</td>
<td>99.5708</td>
<td>0.0089</td>
<td>0.0504</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

In this study the banknote authentication dataset that obtained from UCI Machine Learning Repository have been used for classification of banknotes as genuine or counterfeit. This data set consists of 4 attributes created from banknote images. For classification 12 machine learning algorithm (Multilayer Perceptron, kNN, J48, Naïve Bayes, Bayes Net, KStar) have been used. The success rates and error values have been obtained for the mentioned machine learning algorithms. The best classification success rate have been obtained by using MLP model when there are 4 neurons in the hidden layer. In this situation the obtained success rate, MAE and RMSE error values are 100%, 0.0036 and 0.0115 respectively.

REFERENCES

SPEED CONTROL OF DC MOTOR USING TYPE-2 FUZZY CONTROLLER

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Abstract—In this study, a type-2 fuzzy controller is designed for the speed control of a DC motor. The type-2 fuzzy controller can handle the rules of which membership functions cannot be fully determined or the rules which involve many uncertainties because the type-2 fuzzy controller contains type-2 fuzzy sets for its antecedent and consequent membership functions. The designed type-2 fuzzy controller serves the change in control signal as output according to the input values which are the error values and the error change values. The developed type-2 fuzzy logic controller has been simulated in MATLAB/SIMULINK. The simulation results show that the proposed type-2 fuzzy controller has a high performance for the speed control of a DC Motor.

Keywords—DC Motor, fuzzy control, type-2 fuzzy, PI type fuzzy

I. INTRODUCTION

Direct Current (DA) motors are frequently utilized in open and closed circuit applications in the industry. Majority of these applications require control to ensure high performance [1]. Acquisition of high performance in industrial applications is crucial. In the present study, chopper direct current drivers which display high efficiency, flexible control capability and small and light-weight physical characteristics in number of applications were employed [2-3]. Speed and load fluctuations on DC motors are undesired circumstances. Difficult hardware infrastructure of control methods and their dependency to mathematical modeling allow formation of control methods through various artificial intelligence-based control systems.

Type-1 fuzzy logic systems are not capable of directly tolerating some uncertainties because they use Type-1 fuzzy. Type-2 fuzzy set concept was entered by Zadeh as an extension of traditional fuzzy set concept known as Type-1 fuzzy sets [4]. On the other hand, Type-2 fuzzy logic systems are useful especially when it is difficult to determine certain membership function for a fuzzy set. Thus, Type-2 fuzzy logic systems could be utilized to eliminate uncertainties related with rules and even with measurements [5,6].

In the present study, a driver circuit application controlled by the armature current GTO (Gate Turn Off) thyristor was taken into consideration through the MATLAB/Simulink and electro-mechanical system was controlled by the control system. Regarding the speed control of the DC motor, results were acquired by harnessing the Type-2 fuzzy logic within the Matlab/Simulink environment.

II. DC MOTOR

Direct current (dc) choppers give direct potential applied its entrance by transforming it into a different potential value at its exit by means of the switching element. Direct current choppers encountered in numerous direct potential application cases use choppers rather extensively [7].

DC motor constitutes an open foundation for advanced control algorithms of electric appliances. DC motor is perceived as a SISO system in terms of control systems [8].

Dynamics of a DC motor is described by the following equation:

\[ K_{po}(t) = -R(t) - L \frac{di(t)}{dt} + V(t) \]  \hspace{1cm} (1)

\[ K_{i}(t) = J \frac{d\omega(t)}{dt} + D\omega(t) + T_{f}(t) - T_{L} \]  \hspace{1cm} (2)

where the parameters [8] of the DC motor are shown in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Definition</th>
<th>Symbols</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rotor speed</td>
<td>\omega_0(t)</td>
<td>rad s(^{-1})</td>
</tr>
<tr>
<td>2</td>
<td>Armature resistance</td>
<td>R</td>
<td>\Omega</td>
</tr>
<tr>
<td>3</td>
<td>Armature inductance</td>
<td>L</td>
<td>H</td>
</tr>
<tr>
<td>4</td>
<td>Armature current</td>
<td>i(t)</td>
<td>A</td>
</tr>
<tr>
<td>5</td>
<td>Load torque</td>
<td>T_L</td>
<td>N m</td>
</tr>
<tr>
<td>6</td>
<td>Rotor inertia</td>
<td>J</td>
<td>kg m(^2)</td>
</tr>
<tr>
<td>7</td>
<td>Is torque constant</td>
<td>K_I</td>
<td>V s rad(^{-1})</td>
</tr>
<tr>
<td>8</td>
<td>Back EMF constant</td>
<td>K_P</td>
<td>V s rad(^{-1})</td>
</tr>
<tr>
<td>9</td>
<td>Viscous friction coefficient</td>
<td>D</td>
<td>N m s rad(^{-1})</td>
</tr>
<tr>
<td>10</td>
<td>Coulomb friction torque</td>
<td>T_f</td>
<td>N m</td>
</tr>
<tr>
<td>11</td>
<td>Armature voltage</td>
<td>V(t)</td>
<td>v</td>
</tr>
</tbody>
</table>

III. TYPE-2 FUZZY LOGIC

Fuzzy logic (BM) and Fuzzy Set (BK) Theories were first introduced by Ph.D. Lotfi A. Zadeh in 1965 [9]; and embraced quite extensive practice area. Fuzzy logic is applied in numerous research areas such as Fuzzy Math, Fuzzy Systems, Fuzzy Decision Making and Artificial Intelligence. In the meantime, the Type-2 Fuzzy Set Concept was also introduced by Zadeh [10]. Then, Mendel and his students [11,12] and Turksen [13,14] have improved the Type-2 Fuzzy System Theory on the basis of the Fuzzy Set Concept. Similar to the Type-1 Systems, the Type-2 Fuzzy Systems are comprised of “If-Then” rules as well. However, entry and exit membership sets are the Type-2 Sets in these. When certain membership function is difficult to find for Fuzzy Sets, utilization from the...
Type-2 Fuzzy Sets is extremely beneficent to cope with uncertainties. The Block Diagram indicating the structure of a Type-2 Fuzzy System was exhibited in Figure 1 [5,6].

![Figure 1. Structure of a Type-2 Fuzzy Logic System](image)

**IV. TYPE-2 FUZZY CONTROL OF A DC MOTOR**

In Figure 2, the block diagram of the Type-2 fuzzy control system was exhibited for chopper-fed DC motor. A PI-type controller was designed in this system. Entry variables of the Type-2 fuzzy controller error (e) and change of error (de); exit variable is “ref Δu”. In order to create the controller structure of Type-2 Fuzzy, IT2-FLS Matlab/Simulink Toolbox was harnessed [15].

![Figure 2. The Type-2 fuzzy logic controller used in controlling of a DC motor](image)

**Rule structure in the Type-2 Fuzzy System:***

\[ R^k : \text{IF } e \text{ is } P^{k}_{e} \text{ and } de \text{ is } P^{k}_{de} \text{ THEN } Δu = w^{k}_{1} + w^{k}_{2} \]

\[ k = 1, \ldots, M \]

Type-2 fuzzy sets with \( P^{k}_{e} \) and \( P^{k}_{de} \) interval; where \( w^{k}_{1}, w^{k}_{2} \) are left and right limits of the singleton exit membership functions. Whereas Figure 3 and Figure 4 exhibit the membership functions of entries and exits of the Type-2 fuzzy control system; Table 2 exhibits rule table of the system.

![Figure 3. e input membership function](image)

**Table 2. RULE TABLE OF THE TYPE-2 FUZZY SYSTEM**

<table>
<thead>
<tr>
<th>e</th>
<th>NL</th>
<th>NM</th>
<th>NS</th>
<th>Z</th>
<th>PS</th>
<th>PM</th>
<th>PL</th>
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<tr>
<td>NL</td>
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<td>NL</td>
<td>NL</td>
<td>NL</td>
<td>NM</td>
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<td>Z</td>
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<tr>
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<td>NL</td>
<td>NS</td>
<td>Z</td>
<td>PS</td>
<td>PM</td>
<td>PL</td>
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<tr>
<td>Z</td>
<td>NL</td>
<td>NM</td>
<td>NS</td>
<td>Z</td>
<td>PS</td>
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<td>PL</td>
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<tr>
<td>PS</td>
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<td>Z</td>
<td>PS</td>
<td>PM</td>
<td>PL</td>
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<td>PL</td>
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<tr>
<td>PM</td>
<td>NS</td>
<td>Z</td>
<td>PS</td>
<td>PM</td>
<td>PL</td>
<td>PL</td>
<td>PL</td>
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<tr>
<td>PL</td>
<td>Z</td>
<td>PS</td>
<td>PM</td>
<td>PL</td>
<td>PL</td>
<td>PL</td>
<td>PL</td>
</tr>
</tbody>
</table>

**V. THE MATLAB SIMULINK MODEL**

Figure 5 exhibits chopper-fed DA motor driver in the SimPowerSystem [16].

![Figure 5. The MATLAB/Simulink Model](image)

DA motor is fed by the chopper circuit comprised by the GTO (Gate Turn Off) thyristor connected to the DC resource and a free D1 diode connected to this. Where J refers moment of inertia of the mechanical load driven by the motor; B refers frictional moment; and TL refers the torque loading. Non-hysteresis current controller compares the received signal with the reference signal; and sends trigger signal to the GTO thyristor so that motor current could follow the reference value. The speed control cycle generates reference for the Type 2 Fuzzy controller current cycle. Scope was utilized in order to monitor current and potential signals. As an initial condition, \( \omega=120 \text{ rad/s} \) and \( TL=5 \text{ Nm} \) were taken as reference values [16].
VI. RESULTS

Figure 6 exhibits the plotted graph displaying the change in speed measured at the exit of the system in which Type-2 fuzzy controller was used. It is possible to observe with the MATLAB SimPowerSystem that suggested system was able to reach the reference value of 120 rad/s without exceeding.

![Figure 6. Output of the Type-2 Fuzzy Controller](image1)

Figure 7 exhibits the change in error observed in the Type-2 fuzzy controller system over the time. According to the plotted graph, it was observed that error reduced zero.

![Figure 7. Change in Error in the Control System Over the Time](image2)

As a result of monitoring of the Type-2 Fuzzy Controller in the MATLAB/Simulink environment, change in signs of Va, Ia and motor over the time was exhibited in Figure 8. Where, Va refers chopper exit potential; Ia refers armature current; and these were the graphs plotting the change in Speed w.r.t motor speed over the time.

![Figure 8. Change in Va, Ia and Motor Speed in a Control System over the time](image3)

According to the results obtained by means of the Type-2 fuzzy controller, it was observed that controller acquired the reference speed shortly without exceeding the determined value.

REFERENCES

State-Space Modelling and Realization of Flyback Converter Circuit

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Abstract— Flyback converter circuit is a type of DC-DC converter circuits widely-used in industry. This paper presents analysis and modelling of flyback converter circuit using state-space technique. Switching elements in the converter are modelled with ideal switch concept. The model of flyback transformer and system equations concerning every topology are given. The circuit is realized. Experimental waveforms are compared with the analysis to show the correctness of the modelling and analysis.

Keywords— Flyback DC-DC converter, state-space model, analysis

I. INTRODUCTION

Flyback converter is a type of DC-DC converter circuits. It is widely used in industry because of some advantages: (i) it provides an complete isolation between input and output, (ii) One can get multiple and high voltage outputs, (iii) it is the simplest one if compared with other isolated DC/DC converter types, (iv) it is cheap and practical to implement. Besides these advantages, it requires a protection for leakage inductance and because of the B-H curve limitations it is designed for maximum 150W power applications. Depending on the applications, the flyback DC-DC converter can be operated in two different modes. These modes are continuous conduction mode (CCM) and discontinuous conduction mode (DCM). The proposed model in this study is suitable for both continuous conduction mode (CCM) and discontinuous conduction mode (DCM).

Electronic circuits which use integrated-circuits need a standard DC voltage of fixed magnitude. In some electronic equipment, one may need multiple output power supplies. These DC power supplies are generally provided from the standard power source i.e. AC voltage. For low power applications, the most preferred converter is flyback. The circuit topology of flyback converter is the simplest if we compare it with other isolated DC-DC converters used in the switch mode power supplies (SMPS) [1]. The input given to the converter is generally unregulated DC voltage which is obtained by rectifying the AC voltage followed by a capacitor filter. Flyback converter uses a transformer so that they can give single or multiple isolated output voltages. We talk about energy efficiency, the flyback converter is not good as compared with other SMPS circuits though its topology is very simple [2]. It is presented a simple methodology to design flyback converter with parasitic components in [3]. The authors realize the small-signal analysis of flyback converter. Ref.[4] gives analysis of different flyback converter topologies: Active clamp converter, converter with RCD snubber, interleaved converter, two switch converter, Dual AC and DC output converter. Functionalities of these converters are simulated and their results are compared. Active clamp flyback converters, the one of the most popular flyback converters, are analysed, designed and implemented in [5-9]. The resonant flyback converters [10] were proposed to increase the system efficiency and reduce the switching losses. In Ref.[11], based on the mechanism that the primary and secondary currents of flyback converter do not appear at the same time, two different equivalent models of flyback transformer are brought forward correspondingly. In Ref. [12, 13], the authors analysed the influence of transformer parasitic to low power high voltage output flyback converter by utilizing the simplified transformer model.

The objective of this paper proposes an effective modelling and analysis method for Flyback Converter. The structure of the paper is as follows. Section 2 explains fundamental properties and working stages of flyback converter. In Section 3, first, the flyback transformer is modelled with an ideal transformer and a magnetizing inductor, then, system equations concerning every topology are obtained. Experimental and simulation results are given and compared in Section 4. The paper closes with conclusions in Section 5.

II. BASIC FLYBACK CONVERTER CIRCUIT

The basic flyback converter circuit is shown in Fig.1. It has a transformer, a main switch, (Q), a diode (D), a filter capacitor, a load (R), an input (E). In the circuit, Ip and Is state primer current and secondary current of the transformer, respectively. The converter operates in two stages according to the states of the main switch (Q). Mode 1: when the main switch (Q) is on-state and the diode is off-state, and Mode 2: when the main switch (Q) is off-state and the diode is on-state.

Stage 1: In this mode, the main switch (Q) is turned on-state, the primary winding of flyback transformer is connected to the supply. The current and magnetic flux in the primary side are increased and energy is stored in it. While the potential induced in the secondary winding has opposite polarity than the primary winding, it causes the diode (D) to
get reverse biased and as a result the diode doesn’t allow current through it. The output filter capacitor (C) supplies energy to the load.

Stage 2: It starts when the main switch is turned off-state after conducting. Since the main switch (Q) is open, the current and magnetic flux in the primary side are decreased. According to laws of magnetic induction, the voltage polarities across the windings get reversed. So now, the positive voltage is induced in secondary side and the diode is forward biased. Energy stored in the transformer is delivered to output capacitor and the load.

![Fig. 1 Basic flyback converter circuit](image1)

The major advantage of flyback converter is its filtered output, which eliminates inductive filter, saving cost and volume. High voltage freewheeling diode is also eliminated. Because of this, flyback converters are suitable for high load voltages compared with forward converters. Moreover, in flyback converter, it is possible to get multiple outputs through multiple secondary windings.

III. MODELLING OF CONVERTER CIRCUIT AND SYSTEM EQUATIONS

The flyback transformer is the most complicated as well as the most important component in a flyback DC-DC converter. Before giving the detailed converter model, the flyback transformer must be modelled. Different purposes and different requirements often lead to different equivalent models. In this paper, the transformer is modelled by magnetizing inductor \( L_m \) and ideal transformer, which includes two controlled sources, as shown in Fig. 2. Here, \( U_1 = -nU_2 \), \( J_2 = nI_1 \) (\( n \): turn ratio). Transformer leakage inductances and resistances are ignored to simplify the analysis of the converter.

![Fig. 2 Model of flyback transformer](image2)

After adding the equivalent circuit concerning flyback transformer into the converter, the exact equivalent circuit relating to the flyback converter is obtained as in Fig. 3. Although primary and secondary currents of flyback converter do not appear at the same time, only one equivalent circuit model for transformer is used during a period. The model is valid for both continuous conduction mode (CCM) and discontinuous conduction mode (DCM).

![Fig. 3 Exact equivalent circuit of flyback converter](image3)

In system analysis, state-space analysis technique is used because it has min. variables [14]. The converter circuit has two topologies according to the states of the main switch (Q). Every topology and the relevant space equations are given as follows. The unknowns of system equations are state variables: The current through the magnetizing inductor, \( I_{LM} \), and voltage across the capacitor, accordingly output voltage, \( U_C \).

Switching elements in the converter are modelled with ideal switch concept [15]. This model has zero resistance in the on-state (short-circuit element) and infinite resistance in the off-state (open-circuit element). It provides the most insight in the behaviour of circuits and the fastest simulation.

A. The Topology 1: The main switch is on-state, the diode is off-state

In this topology, the main switch turns on-state by control signal and the diode turns off-state because of the negative induced voltage in secondary winding. During this part of period, the magnetizing inductance (Lm) stores energy and the output capacitor supplies the load. The equivalent circuit is given in Fig. 4.

![Fig. 4 Topology 1: Main switch is on-state, Diode is off-state](image4)
\( i_c = C \frac{du_c}{dt} = -i_R \) \hspace{1cm} (1)

\( u_{LM} = L_m \frac{di_{LM}}{dt} = E \) \hspace{1cm} (2)

\[
\frac{d}{dt}\begin{bmatrix} u_c \\ i_{LM} \end{bmatrix} = \begin{bmatrix} -1/RC & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} u_c \\ i_{LM} \end{bmatrix} + \begin{bmatrix} 0 \\ 1/L_m \end{bmatrix} E
\] \hspace{1cm} (3)

B. The topology 2: The main switch is off-state, the diode is on-state

In this topology, the main switch turns off-state after conducting (by cutting off control signal) and voltages polarities across the windings gets reversed. The energy stored in magnetizing inductor supplies the capacitor and the load. The equivalent circuit is given in Fig.5.

![Fig. 5 Topology 2: Main switch is off-state, Diode is on-state](image)

The state-space equations concerning the equivalent circuit in Fig 5 are obtained in Eq.(6).

\[
u_{LM} = L_m \frac{di_{LM}}{dt} = U_1 = -nU_2 = -nu_c
\] \hspace{1cm} (4)

\[
i_c = C \frac{du_c}{dt} = -i_R - i_2 = -\frac{u_c}{R} - ni_1 = -\frac{u_c}{R} + ni_{LM}
\] \hspace{1cm} (5)

\[
\frac{d}{dt}\begin{bmatrix} u_c \\ i_{LM} \end{bmatrix} = \begin{bmatrix} -1/RC & n/C \\ -n/L_m & 0 \end{bmatrix} \begin{bmatrix} u_c \\ i_{LM} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} E
\] \hspace{1cm} (6)

IV. EXPERIMENTAL AND SIMULATION RESULTS

The converter has been designed to have 34V DC output from 220V, 50Hz AC supply. The first step is to convert AC voltage to DC voltage, a rectifier circuit is used. Then, unregulated DC voltage is filtered using a capacitor (called as link capacitor) and this output is given to a DC to DC converter, single ended isolated flyback converter. The power MOSFET is used for the switching of the converter. The specification of MOSFET are N-Channel, 650V, 5.4A, 400mΩ. The value of switching frequency is chosen so that the circuit can be worked at high frequency and obtain a minimized circuit dimension. Specification of the converter is given in Table 1.

![Fig. 6 Experimental waveform of output voltage](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line Voltage</td>
<td>220V AC</td>
</tr>
<tr>
<td>Line Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Input Voltage of Converter (Emin, Emax)</td>
<td>90V-240V</td>
</tr>
<tr>
<td>Output Power</td>
<td>24W (34V, 0.7A)</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>34V</td>
</tr>
<tr>
<td>Duty Ratio (D)</td>
<td>0.17</td>
</tr>
<tr>
<td>Flux Density (Bsat): for Ferrite Core</td>
<td>0.22T</td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>65 kHz</td>
</tr>
<tr>
<td>Magnetiizing Inductor</td>
<td>370µH</td>
</tr>
<tr>
<td>Turn Ratio (n)</td>
<td>2.27</td>
</tr>
<tr>
<td>Output Capacitor</td>
<td>990µF</td>
</tr>
<tr>
<td>Load Resistor</td>
<td>50Ω</td>
</tr>
</tbody>
</table>

![Fig. 7 Experimental waveform of output current](image)

As shown from Fig.8, during the on-state of MOSFET, the primer current of transformer is increased linearly, this result is compatible with Topology 1 in Fig.4. Similarly, as shown from Fig.9, during the off-state of MOSFET, the seconder current of transformer is decreased linearly, this result is compatible with Topology 2 in Fig.5.
The flyback converter circuit with the design parameters in Table I are simulated with MATLAB using state-space equations (3) and (6). The result is illustrated in Figure 10. Since the input of converter has a ripple voltage, the output voltage in Fig.10 has a wide range oscillation. As shown from Fig. 10, the min. and max. simulation values of output voltage are: 30V-49V.

The simulation and the experimental results concerning the output voltage are compared. These experimental results can verify the modeling and analysis in this paper very well.

**V. CONCLUSION**

Flyback Converter is used in various applications due its less complexity, cost effectiveness, multiple output and isolation. In this paper, the flyback transformer, the most important component of the converter, is modeled with an ideal transformer and a magnetizing inductor. Although the primary and secondary currents in the transformer do not appear at the same time, only one equivalent model for the flyback transformer is brought forward. By using this equivalent model, the working process of the flyback DC-DC converter under DCM mode is analyzed. The flyback converter topologies are analyzed by state-space technique. Experimental results of a real converter are presented to show that the working process can be well explained through the models presented in this paper.

**REFERENCES**


Study on Power Factor Correction Using Fuzzy Logic Excitation Control of Synchronous Motor

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Abstract — The correction of power factor in electric power systems is called reactive power compensation. A synchronous motor is used as a capacitive reactive power generator in compensation systems. It is less costly for an enterprise to use a synchronous motor as both mechanical power generator and power factor corrector, which increases their efficiency. There are various studies on increasing the efficiency, capacity and stability of a power system using power factor correction under different operating conditions. This study focuses on the power factor correction of the system by controlling the excitation current of the synchronous motor via fuzzy logic thanks to the asynchronous motor connected to the system.

Keywords — Power factor, Fuzzy Logic, Synchronous Motor

I. INTRODUCTION

As a result of technological improvements, energy consumption has increased in recent years due to the increasing use of inductive loads in industrial applications. Besides active power, inductive loads also absorb reactive power from the grid [1]. Although reactive power absorbed from the transmission line feeds, it cannot be converted to the energy [2]. Therefore, reactive power absorbed from the grid causes losses in electric power systems, and these losses must be minimized. The minimization of energy losses will reduce cable and other measurement and protection costs, thus creating a more cost-effective electric power system. This can only be achieved when reactive power needed by the inductive loads, which the transmission line feeds, is supplied to the load as closely as possible. Reactive power needed by the loads is supplied statically by a capacitor or reactor and dynamically by a synchronous motor [3-5]. Reactive power compensation via a synchronous motor can be achieved by changing the excitation current of the motor if the motor operates in a capacitive or inductive character [6]. In addition, the amount of reactive power that a synchronous motor absorbs from the grid can be adjusted thanks to the excitation current. An efficiently compensated system will improve the power factor, minimize losses and become efficient [7-9].

This study focuses on the power factor correction of an electric power system using a fuzzy logic based and excitation current controlled synchronous motor. Because it is difficult to determine control parameters via methods requiring mathematical models when a synchronous motor is used for power factor correction, a fuzzy logic based compensation control system was used in this study.

II. POWER FACTOR

Reactive power compensation plays an important role in the improvement of efficiency and capacity of electric power systems. The current of inductive power consumers is supplied by two components of the current. The former is active current converted to work while the latter is reactive current which creates the necessary magnetic field for electric machinery and devices.

Types of power corresponding to these currents are:

\[ S = \text{Apparent Power (VA)}, \]

\[ P = \text{Active Power (W)}, \]

\[ Q = \text{Reactive Power (On)}, \] then

\[ S = \sqrt{P^2 + Q^2} \]  \hspace{1cm} (1)

the equation above can be obtained, which can be geometrically defined as a power triangle as shown in Fig.1.

![Power triangle](image)

Here, \( \phi \) is defined as the phase angle. \( \cos \phi \) is the power factor, which is defined as follows [12].

\[ \cos \phi = \frac{P}{S} \]  \hspace{1cm} (2)

III. SYNCHRONOUS MOTOR

Synchronous motor is an alternative current motor in which rotor rotational speed is equal to the rotational speed of the stator rotating field and the rotation speed does not vary in
loading. When excitation current of the synchronous motor changes, it absorbs ohmic, inductive and capacitive current [13]. In a synchronous motor operating at a constant load and voltage, the characteristic which yields the relationship between excitation current and stator current is called V-current. The point at which excitation current forming the lowest load current at a constant load exists is called ohmic operating point of the motor. The synchronous motor operates inductively under an excitation current lower than that of the ohmic operating point while it operates capacitively under an excitation current higher than that of the ohmic operating point. V-curves which account for the relationship between load current and excitation current for different loads of the synchronous motor are shown in Fig. 2.

As shown in Fig. 2, V-curve of the synchronous motor varies based on different loads. V-curves are at the outermost part when the motor operates at an unloaded state, and they come closer to the ohmic operation curve as the motor is loaded. In case of ohmic operation, the necessary excitation current in the unloaded state increases in a directly proportional way to the load, which is because armature reaction varies depending on the various loads and the saturation increases.

IV. FUZZY LOGIC CONTROL

Fuzzy logic is defined as a mathematical order created in order to explain fuzzy situations and work under fuzzy conditions. Fuzzy logic can control systems when knowledge and predictions about the system are placed within it. In other words, a mathematical model of the system to be controlled is not needed. Fuzzy logic control system consists of four basic units: general fuzzification, inference, defuzzification and rule base [15]. A block diagram of a general fuzzy logic controller is shown in Fig. 3.

Fuzzification is the process of converting inputs obtained from the system to linguistic qualifiers as symbolic values. The fuzzy clusters and membership degrees to which inputs belong are identified thanks to the membership function, and linguistic values such as big or small are assigned to the numerical values.

Fuzzy inference unit creates fuzzy results by applying fuzzy values obtained from the fuzzification unit to the rules in the rule base. The connection between inputs and outputs is created using rules in the rule base. The value obtained in this unit is converted to a linguistic expression based on the rule table and transferred to the defuzzification unit. This study benefits from Mamdani method, which is the most widely used method among fuzzy inference methods.

Defuzzification unit helps distinguish between the non-fuzzy real value to be applied and fuzzy knowledge transferred from the decision unit. Defuzzification is the process of converting fuzzy knowledge to precise results. Various methods are used in defuzzification process. Among these methods, center of gravity method is the most widely used defuzzification method. The equation for this method is given in equation 3.

\[ y = \frac{\sum_{i=1}^{n} y_i \mu_A(y_i)}{\sum_{i=1}^{n} \mu_A(y_i)} \]  

Knowledge base is a data table consisting of knowledge related to the system to be controlled. The connections between inputs and outputs are created using rules in the rule base. If a rule base is to be developed for a system, input values that may influence system output must be identified [16-17].

V. FUZZY LOGIC CONTROLLER DESIGN

V-curves of the synchronous motor and reactive power that it absorbs from the grid were used to design fuzzy logic controller in this study. Fig. 4 and 5 were drawn based on the data obtained from the performance of synchronous motor under nominal conditions. Based on these graphs, the reactive power that the synchronous motor absorbs from the grid and changes in the excitation current of the synchronous motor eliminated the need for a mathematical model, and thus a power factor correction was performed via the synchronous motor based on fuzzy logic.
Input variables of the fuzzy logic control unit designed for this study were determined as error (e), Q (reactive power) and output variable (I_E). Error (e) is found when power factor value is subtracted from input reference power factor value as given in equation 4.

\[ e = \cos \phi_{\text{ref}} - \cos \phi_{\text{inst}}. \]  

(4)

Q (reactive power) as an input variable is applied to the controller input, and its unit is ‘Var’. Output variable (I_E) denotes the current flowing through excitation windings of the synchronous motor, and its unit is ampere. Five different linguistic variables, NB (Negative Big), NS (Negative Small), Z (Zero), PS (Positive Small) and PB (Positive Big), are defined for error (e), Q (reactive power) and excitation current (I_E), which are the variables of the fuzzy logic controller unit. Membership functions in the form of triangles and trapezoids were designed for error, reactive power and excitation current. These membership functions are shown in Fig. 7, 8 and 9.
Five membership functions that are widely used in the designed fuzzy logic controller unit were assigned, and they proved to be suitable for this study. The sum of control rules are twenty-five. Fuzzy rules are given in table I.

<table>
<thead>
<tr>
<th>Ie</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB</td>
<td>NB</td>
</tr>
<tr>
<td>NS</td>
<td>NB</td>
</tr>
<tr>
<td>Z</td>
<td>NB</td>
</tr>
<tr>
<td>PS</td>
<td>NS</td>
</tr>
<tr>
<td>PB</td>
<td>Z</td>
</tr>
</tbody>
</table>

As far as the performance of fuzzy controller is concerned, rule base uses existing knowledge about the behavior of a system to be controlled instead of a mathematical model of the system. Such knowledge is used during design process, which helps placing long standing experiences in the system following a process of interpretation [19].

VI. SIMULATION STUDIES

Power factor is a parameter that measures the efficiency of electricity energy. The efficiency of electric power system is directly proportional to its power factor. Asynchronous motors possess feedback power factor. The power factor of synchronous motor can feed back or forward when the excitation current is adjusted. The values of the asynchronous motor and synchronous motor used in the simulation study are given in table II and III.

Table II. Asynchronous motor parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Power(P)</td>
<td>3 kW</td>
</tr>
<tr>
<td>Nominal Revolution[n]</td>
<td>1430 rpm</td>
</tr>
<tr>
<td>Nominal Voltage(V)</td>
<td>400 V</td>
</tr>
<tr>
<td>Nominal Current(I)</td>
<td>6.7 A</td>
</tr>
<tr>
<td>Nominal Load Torque(M)</td>
<td>19 Nm</td>
</tr>
<tr>
<td>Pole pairs(p)</td>
<td>2</td>
</tr>
<tr>
<td>Frequency(f)</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Rotor Type</td>
<td>Squirrel-cage</td>
</tr>
</tbody>
</table>

Five membership functions that are widely used in the designed fuzzy logic controller unit were assigned, and they proved to be suitable for this study. The sum of control rules are twenty-five. Fuzzy rules are given in table I.

<table>
<thead>
<tr>
<th>Table III. Synchronous motor parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>Nominal Power(S)</td>
</tr>
<tr>
<td>Nominal Revolution[n]</td>
</tr>
<tr>
<td>Nominal Voltage(V)</td>
</tr>
<tr>
<td>Nominal Field Current(I)</td>
</tr>
<tr>
<td>Nominal Load Torque(M)</td>
</tr>
<tr>
<td>Pole pairs(p)</td>
</tr>
<tr>
<td>Frequency(f)</td>
</tr>
<tr>
<td>Rotor Type</td>
</tr>
<tr>
<td>Stator Resistance[R_s]</td>
</tr>
<tr>
<td>Stator Inductance[L_s]</td>
</tr>
<tr>
<td>Field Resistance[R_e]</td>
</tr>
<tr>
<td>Field Inductance[L_e]</td>
</tr>
<tr>
<td>Mechanical Inertia[J]</td>
</tr>
<tr>
<td>Friction Factor[F]</td>
</tr>
</tbody>
</table>

When voltage is applied to the stator windings of the synchronous motors, they cannot move forward due to their inertia. Therefore, several methods exist to start the synchronous motor. In the present study, the synchronous motor was started as if it were an asynchronous motor.

As shown in Fig.10, the synchronous motor reached a synchronous speed after it moved for 0.9 seconds. Afterwards, an excitation current of 5 percent is applied to the synchronous motor via fuzzy controller, which supplied reactive power in a capacitive character to the power system of the synchronous motor. Thus, the synchronous motor compensated itself and fixed the power factor of the system at 0.98, which was 0.8 at the beginning.

VII. CONCLUSION

In the present study, a fuzzy logic control method was used in order to create a more sensitive power system performance and increase system efficiency instead of a conventional control system requiring mathematical models for the calculation of controller parameters. During the operation of control system, the excitation current of the synchronous motor, the reactive power that it absorbs from the grid and its power factor were constantly observed. These values were evaluated in the rule table, and it was aimed to more effectively apply the change in the excitation current of synchronous motor to the system. Contrary to previous studies, this new fuzzy logic control
method increases the power factor to a more favorable level by effectively adjusting the excitation current based on the reactive power that the synchronous motor absorbs from the grid.

REFERENCES


Chaotic encryption based data transmission using Delta and Delta-Sigma modulators

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Abstract—Delta and Sigma-Delta modulation methods have been getting a great interest recently due to the great progress in analog-digital very large scale integration technology. Since the outputs of these methods are digital, the data can be securely encrypted using very simple standard hardware. In this work, a chaotic random bit generator based approach for encrypting digital data of the delta and delta-sigma modulators is studied. The chaotic bit generation can easily be implemented in the digital hardware of the modulators due to simplicity of the chaotic dynamics. The randomness of the generated chaotic bits are proved with visual and statistical tests. The security of the proposed approach is evaluated via key space estimation based attacks. The efficiency of the methods is validated with simulations.

Keywords—Chaos, delta modulation, delta-sigma modulation, random bits, cryptography, communication

I. INTRODUCTION

The delta (Δ) and delta-sigma (ΔΣ) modulators offer simple, efficient methods for telecommunication and signal processing applications. The Δ modulation systems have gained significance in recent years due to their very simple hardware structure, digital transmission and easy to add adaptive features. In addition ΔΣ modulators have noise shaping feature that makes them well-suited for low-frequency, high-accuracy measurements. There are many applications of Δ modulators including reliable voice communications, analog-to-digital signal conversion, performing audio delay lines, telemetry systems and feedback power control in code-division multiple-access radio communication systems [1]–[5]. The Δ modulation systems, a type of variable structure control, are also getting a special interest in the control community [6]–[10]. Other recent studies on Δ modulators have been focused on multibit modulation, chaotic modulation, chaoticification and tone suppression in communications [11]–[17].

The digital output of the Δ modulation systems can be encrypted by using chaotic systems. Since chaotic dynamics have strong similarities with the cryptography, e.g., aperiodicity, deterministic dynamics, ergodicity and sensitivity to initial conditions, they have recently been utilized in cryptosystems [18]–[23]. To encrypt the Δ modulation systems, while the required random bits can be generated from a hardware-based generator (e.g., using thermal noise [24] and radioactive decay [25]) or from software-based generators (e.g., linear congruential generators [26]), chaotic systems are very simple to realize and offer a hybrid structure with the features of hardware and software based approaches [27]–[30]. The number of the chaotic systems have been increased over time in the literature, which allows us to benefit from chaotic dynamics for generating efficient chaotic random bits for use in cryptographic applications [31]–[35].

In this work, a chaotic random bit generator is developed and integrated into the Δ and ΔΣ modulators for data encryption. The goal is to provide security in such systems during data transmissions. The Δ modulation systems offer low cost solutions with a strong immunity against crosstalk and noise in the transmission line, and integration of the chaos into these systems will enhance reliability and security.

In the following sections, the Δ modulation methods are overviewed and a chaotic map based encryption scheme is applied to digital outputs of the Δ and ΔΣ encoders.

II. CHAOTIC DATA ENCRYPTION FOR Δ AND ΔΣ MODULATION

Chaotic systems are able to provide diffusion and confusion, i.e., hiding and spreading plaintext over the ciphertext, and for this reason have potential applications in some functional blocks of communication systems including encryption, modulation and compression. By considering a delta modulation scheme, the chaotic random bits can easily be used for encrypting digital plaintext for secure communications. Figure 1 shows a chaos based digital data encryption and decryption approach for Δ modulators.

Fig. 1 Chaos based encryption for delta modulation system

Similarly, the chaotic bits can also be incorporated into digital output of the ΔΣ modulator and demodulator systems for securing the data as illustrated in Fig. 2. In data encryption the exclusive-or (XOR) logical function is used. The Δ modulated signals are easily demodulated at the receiver by
using a low pass filter, but now with the chaotic encryption, it is not possible to extract message without correct chaotic decrypter with correct initial conditions and parameter values.

\[ \dot{x} = x(t) - \delta \text{sign}(x(t)) \]  

(1)

where \( u(t) \) is the input signal, \( n(t) \) is the integrator output, \( x(t) \) is the error signal and the quantization level is given by \( \pm \delta \). The \( \text{sign}(.) \) function is defined by \( \text{sign}(x) = 1 \) if \( x \geq 0 \), and \( \text{sign}(x) = -1 \) if \( x < 0 \). In order to make the \( \Delta \) modulator function correctly, the error must be forced to zero in finite time by the feedback signal. To find stability conditions of the \( \Delta \) modulator, if we define a positive definite Lyapunov function as

\[ L = x^2 / 2 \]  

(2)

Then, the time-derivative of (2) can be written as

\[ \dot{L} = x \dot{x} = x(\dot{u} - \delta \text{sign}(x)) \leq -\delta |x| \]  

(3)

Thus, the modulator is stable if the following condition holds

\[ \delta > \max |\dot{u}(t)| \]  

(4)

The equivalent condition for the discrete-time (sampling) implementations is given by

\[ \delta f_s > \max |u(t)| \]  

(5)

where \( f_s \) is the sampling frequency. Equation (5) shows that the \( \Delta \) modulator produces a binary coded output from the time-derivative of the analog input signal.

For \( \Delta \Sigma \) modulators seen in Fig. 2, since the input signal first passes through an integrator, then the governing equation can be written as

\[ \dot{x}(t) = u(t) - \delta \text{sign}(x(t)) \]  

(6)

Similar to (2), if the Lyapunov stability is applied, one can easily obtain the following stability condition

\[ \delta f_s > \max |u(t)| \]  

(7)

Therefore, the \( \Delta \Sigma \) modulators have noise suppression advantage compared to \( \Delta \) modulators because the quantization level is proportional to the amplitude of the input signal (while \( \delta \) is proportional to the derivative of the input signal in \( \Delta \) modulators). This noise-shaping feature of the \( \Delta \Sigma \) modulators is well suited to signal processing applications, e.g. communication and digital audio.

![Fig. 2 Chaos based encryption for delta-sigma modulation system](image)

![Fig. 3 Delta modulation technique](image)
satisfied for the related modulator type. There exist adaptive algorithms for adjusting quantization step size to eliminate quantization errors of the Δ modulator systems. On the other hand, the performance of these modulators is dependent on the quantization and channel noise. The quantization noise averages to zero and can be defined by its root mean square (rms) value for a dynamic input signal by considering its limits ±δ/2. Thus, the quantization error 𝑥(𝑡) is given by

\[ x_{rms} = \sqrt{\frac{1}{\delta} \int_{-\delta/2}^{\delta/2} x^2(t) dt} = \frac{\delta}{\sqrt{12}} \]  

(8)

The noise level is equal to quantization noise of an analog-to-digital converter. For rms value of the input signal \( u(t) \), the signal-to-noise ratio (dB) can be given by

\[ \text{SNR}(dB) = 20 \log \left( \frac{u_{rms}}{x_{rms}} \right) = 20 \log \left( \sqrt{12} \frac{u_{rms}}{\delta} \right) \]  

(9)

In these calculations, These results are valid only for uniformly distributed quantization noise and the effect of the slope overload distortion is ignored. The quantization noise remains the same at the demodulator.

B. Chaotic Random Bit Generation

Many chaotic systems are available in the literature to serve as a source for chaotic random bit generations for use in encryption/decryption algorithms. For such applications both continuous-time and discrete-time chaotic systems can be utilized, but the discrete maps are preferred because of their convenience for digital realizations and superior performances. To acquire random bits in a fast, simple way, the robust chaotic maps can be used since they do not have any periodic windows in a large parameter range of the chaotic behaviour. Robust chaotic maps are defined with piecewise linear and discontinuous maps whose Lyapunov exponents are positive throughout the chaotic parameter range [36]. In addition these maps are able to provide statistically uniformly distributed random numbers, which is critical to generated random bits without performing and de-skewing method. Consider a symmetric tent map described by

\[ \theta_{i+1} = 1 - \eta |\theta_i| \]  

(10)

where \( \eta = 1.9999 \). To show the existence of chaos in the system for \( 1 < \theta \leq 2 \), the Lyapunov exponent and bifurcation diagram of the system are given in Fig. 4 for \( \eta \) versus \( \theta_i \). The map has a positive Lyapunov exponent (LE) when \( \eta > 1 \) with a maximum value 0.672. The bifurcation diagram shows that the map has chaos without any periodic windows for a wide range of parameter variations. The map exhibits a robust chaos since the Lyapunov exponent is always positive in the chaotic region.

Even though, statistical tests are not enough to determine the quality of the randomness, they are needed to get an idea. The randomness features of (10) can be evaluated with the visual and test statistics based methods. Visualization is a quick way to get rough information about the chaotic random sequences. The bifurcation diagram and the histogram plot are used for visual evaluations. Figure 5 displays a histogram plot of the chaotic map for 100 categories. The histogram plot shows a uniform distribution over the ±1 range. This means that the chaotic map with the selected parameter value generates a uniformly distributed random sequence.

Fig. 4 Bifurcation diagram and Lyapunov exponent.

![Fig. 4 Bifurcation diagram and Lyapunov exponent.](image)

Fig. 5 Histogram plot.

Now, since we verify that the chaotic map provides uniformly distributed random numbers, we can generate bits (or binary sequences) from this chaotic map by using a simple comparator defined by

\[ h_i = \begin{cases} 1, & \theta_i \geq 0 \\ 0, & \theta_i < 0 \end{cases} \]  

(11)

The usage of a comparator is a simple, efficient and convenient way to generate binary values from the chaotic source [37]. The chaotic random bits should also be evaluated with some qualitative statistical tests to confirm that the generated random bits are unbiased, uncorrelated random bits. To assess the randomness of the generated random bits, many statistical tests are available in the literature including monobit, serial, overlapping template matching, cumulative sum, poker, autocorrelation, runs, discrete Fourier transform (spectral) and
frequency within a block (or block frequency) tests [38]–[40]. These tests are used to determine whether the chaotic random bits are unbiased and uncorrelated. That is to say, the chaotic random bits \( h_i \) with security bound \( S \) bits should include unbiased bits (probability of 0 and 1 must be equal) and indistinguishable bits without performing at least \( 2^S \) operations [41]. Even though the statistical tests alone are not enough for such evaluations, it is nice to see that the chaotic bits pass all these statistical tests. Note that for practical applications, application-specific tests are usually carried out for randomness analysis. The statistical test results are given in Table I. It is clear that all tests are successfully passed, and for this reason, the robust chaotic map (10) with the binary converter algorithm (11) produces a highly-satisfactory random bits for use in cryptosystems.

### TABLE I

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test Values</th>
<th>Statistics</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monobit</td>
<td>( q &lt; 3.8415 )</td>
<td>1x10⁻⁸</td>
<td>success</td>
</tr>
<tr>
<td>Block frequency</td>
<td>( q &gt; 0.01 )</td>
<td>0.886</td>
<td>success</td>
</tr>
<tr>
<td>Runs</td>
<td>( q &gt; 0.01 )</td>
<td>0.785</td>
<td>success</td>
</tr>
<tr>
<td>Fourier transform</td>
<td>( q &gt; 0.01 )</td>
<td>0.939</td>
<td>success</td>
</tr>
<tr>
<td>Autocorrelation</td>
<td>(</td>
<td>q</td>
<td>&lt; 1.96 )</td>
</tr>
<tr>
<td>Serial</td>
<td>( q &lt; 0.01 )</td>
<td>1x10⁻⁸</td>
<td>success</td>
</tr>
<tr>
<td>Overlapping</td>
<td>( q &gt; 0.01 )</td>
<td>0.998</td>
<td>success</td>
</tr>
<tr>
<td>Cumulative sums</td>
<td>( q &gt; 0.01 )</td>
<td>0.4354</td>
<td>success</td>
</tr>
<tr>
<td>Poker</td>
<td>( q &lt; 14.067 )</td>
<td>9.136</td>
<td>success</td>
</tr>
</tbody>
</table>

### III. SIMULATION RESULTS

The Matlab/Simulink based numerical simulation results are given in Figs. 6-7. Figure 6 shows the chaotic data encryption in \( \Delta \) modulator based data transmission results. The message signal which includes ASCII codes of “chaos” is seen in Fig. 6a. The digital output of the \( \Delta \) modulator is displayed in Fig. 6b, where there are some windows in the modulated signal. This digital signal can easily be demodulated with an integrator and low-pass filter. To encrypt the modulator output bits, the XOR logic function is used for the chaotic bit sequence and the modulator bits, namely,

\[
    w_j = v_j \otimes h_j
\]

Figure 6c shows the encrypted modulator output bits, which does not have any visual pattern. The same chaotic bit generator is used in the demodulator to decrypt the original modulator output bits and then a demodulator is employed to extract the original message signal. The recovered message signal is seen in Fig. 6d, which shows a perfect recovery. The security of the scheme is tested with the use of \( \Delta \) demodulator, low-pass filtering and estimated key sequence-based tests. In Fig. 6e, the test result for a wrong chaotic key sequence is illustrated. In this test, the same chaotic map and binary converter algorithm is used. The initial condition of this eavesdropping system is assumed to be estimated with a very small initial condition error, e.g., \( \gamma = \theta_0 - \theta'_0 = 1x10^{-7} \), and it is seen in Fig. 6e that the message cannot be recovered. The chaotic maps in the transmitter and receiver must be exactly the same with the same parameters and initial conditions to generate the correct key sequence and to decrypt the correct message.

Similarly, the numerical simulation results for the \( \Delta \Sigma \) modulator based data transmission are given in Fig. 7. The waveform of the first-order \( \Delta \Sigma \) modulator is illustrated in Fig. 7a when the input signal is a sinusoid as given in Fig. 7a. It is should be noted that the modulator performs both the sampling and the quantization operation in this example, which is typical in practical circuit implementations. The \( \Delta \Sigma \) modulator output shows that the output is either plus or minus full scale and when the sinusoidal input to the modulator is close to the full scale, the output is either positive or negative during the cycle. It is seen that the local average of the modulator output follows the input signal. When the input signal is around zero, the modulator output changes fast between ±\( \theta \) with nearly zero mean. Therefore, the input signal can easily be recovered by using a low pass filter as...
From security developments in mixed signal integrated circuits, a scheme is designed for very small estimation error. The modified map and binary converter algorithm is used for improving the security of the approach, taking into account the patterns. On the other hand, the chaotic bits based on a chaotic key sequence are used for modulating the message. In this work, we have proven the effectiveness of the chaotic modulation technique in communication systems, where the randomness of the robust chaotic map based random bits are evaluated with qualitative statistical tests. The robustness of the delta modulation systems under chaotic encryption is tested with low pass filtering and key space estimation based attacks, and it is shown that the methods are highly secure and reliable. The use of chaos in securing delta modulation approaches provides a good option to be considered as a framework for the next generation communication and data transmission systems.

**IV. CONCLUSIONS**

A chaotic random bit generator based data encryption scheme is designed for digital transmission through delta and delta-sigma modulators. The practically proven technology of the delta modulation systems are used in many signal processing and communication applications with the developments in mixed signal integrated circuits. The implementation of the chaotic encryption is able to provide security for such systems. The approach allows us to benefit from the advantages of the delta modulation techniques and chaos theory. The randomness of the robust chaotic map based random bits are evaluated with qualitative statistical tests. The security of the delta modulation systems under chaotic encryption is tested with low pass filtering and key space estimation based attacks, and it is shown that the methods are highly secure and reliable. The use of chaos in securing delta modulation approaches provides a good option to be considered as a framework for the next generation communication and data transmission systems.

**ACKNOWLEDGMENT**

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**REFERENCES**


Performance Comparison of PSFB-PWM Converter and LLC Resonant Converter for On-Board Electrical Vehicle Battery Charger

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Abstract—This work presents a performance comparison of phase shifted full bridge (PSFB) converter and inductor-inductor-capacitor (LLC) resonant converter for on-board electrical vehicle (EV) battery charge applications. In the comparison, lithium-ion battery cells are taken into consideration to evaluate the performance of converters because of their high power density. In the performance evaluation, for both converter, soft switching operation of the primary semiconductors is discussed to provide output requirements of the battery. The performance of both converter are also validated experimentally by two prototypes, operating with 810 W maximum output power. Experimental results are obtained in good match with theoretical results. According to obtained results, PSFB converter works with soft switching from 50 V to 54 V output voltage, with constant output current, at 200 kHz switching frequency. LLC resonant converter works with soft switching from 42 V to 54 V but with changing switching frequency between 150 kHz and 200 kHz.

Keywords—On-board battery charge, PSFB converter, LLC resonant converter, li-ion battery charge.

I. INTRODUCTION

The use of electrical vehicle (EV) increases greatly every day since the fossil fuels run out, rapidly. Therefore, EV provides benefits in the area of the economy for the most country in the world. The battery charge of vehicles can be possible from a battery charge station or directly a power outlet with on-board chargers. On-board battery chargers can encourage the user to use EV giving flexibility to charge vehicle’s battery from any power point [1]. However, the volume, weight and the cost of the EV increase with on-board chargers [2]-[6].

The lithium-ion battery cells have high voltage and current rate so their power density is higher compared to the other battery cells [7], [8]. However, larger voltage range of the battery cell brings the need of wide range output voltage regulation for the converter. An on-board battery charger is composed of two stages which are AC –DC conversion stage and DC-DC conversion stage. This work focuses on the second stage of a battery charger. The second stage usually uses soft switching converters to provide high efficiency and high power density. The phase shifted full bridge (PSFB), pulse width modulated (PWM) converter and resonant converters are good candidates, and they are mostly used for the second stage of the battery charger [1], [9]-[11].

The PSFB-PWM converter can operate with SS providing phase delay for the control signals of the cross-conducted primary switches of the converter. However, this soft switching process is affected by load conditions and dead time [12], [13]. The resonant converters operates naturally with soft switching and their soft switching operation doesn’t depend on load condition. However, the resonant converter can regulate the output voltage with the change of switching frequency. Moreover, they have also high conduction loss due to increased rms currents. The LLC resonant converter topology provides the narrow switching frequency compared to series, parallel and series-parallel resonant converter topologies [14]. Therefore, it is usually preferred for battery charge applications [9]-[11], [15] and [16]. It seems both PSFB PWM converter and LLC resonant converter have some advantages and disadvantages. Therefore, the performance of PSFB converter and LLC resonant converter needs to be discussed for battery charge applications.

The lithium-ion battery charge process has wide range load and output voltage condition. Therefore, this work discusses the performance of PSFB PWM converter and LLC resonant converter based on their soft switching operation according to lithium-ion battery charge characteristic. For this purpose, two experimental setup are built to validate presented theoretical evaluations. The built setups were tested for 42-54 V output voltage range with 810 W maximum output power.

II. THE PRINCIPLES OF LLC RESONANT AND PSFB PWM DC-DC CONVERTERS

A. LLC Resonant Converter

A circuit diagram of LLC resonant converter is shown in Fig. 1. In the diagram, resonant tank consisted of L1, Lm and C1, S1, S4 are the primary MOSFETS, D1 and D2 are the rectifier diodes producing dc output voltage. The output voltage is \( v_o \), the output capacitor filter is \( C_o \), the load resistor is \( R_o \). The input voltage is \( v_{in} \) and TR represents the transformer with \( N \) turns ratio.

The voltage gain characteristic of the converter based on normalized frequency, \( f/f_o \), and quality factor, \( Q \), variation is given in Fig. 2 [17].
MOSFETs and works below resonance too, but with capacitive operation. The Region 1 always works with inductive mode. Region 3 is used when the switching frequency is higher than the resonance frequency. The Region 1 works with inductive mode and Region 3 works below resonance too, but with capacitive operation. The converter is usually operated at \( f_1 \) for constant voltage applications to reach maximum efficiency [18]-[21]. However, battery charge application should provide wide range output voltage regulation and this operation can be possible with the varying switching frequency [9], [14].

The Region 1 and 2 provide ZVS operation for the primary switches with the operation in inductive mode. Region 3 presents the capacitive mode and this is not suitable for ZVS operation of primary MOSFETs. Therefore, converter can be operated in Region 1 and 2 according to desired output voltage range.

**B. PSFB PWM DC-DC Converter**

The circuit diagram of PSFB converter is given in Fig. 3. \( S_1 \)– \( S_4 \) represent the primary MOSFETs. \( L_s \) is the snubber inductance. \( L_m \) is the magnetizing inductance. \( D_{S1} \) and \( D_{S2} \) are rectifier diodes. \( L_o \) and \( C_o \) are the output filter components. \( V_m \) is the input voltage source. \( V_o \) is the battery voltage. \( N \) is the turns ratio of the transformer. \( S_1 \)– \( S_4 \) represents the leading leg MOSFETs and \( S_2 \)– \( S_3 \) represent the lagging leg MOSFETs.

In the power stages, two diagonal MOSFETs of each leg are turned on, and in the freewheeling stage, the upper or lower side MOSFET \( (S_f \) or \( S_l) \) and an antiparallel diode of the opposite MOSFET \( (S_f \) or \( S_l) \) are switched on. During the output current commutation, both rectifier diode stays on condition and the secondary side of the transformer is short circuited.

In this converter, SS operation of the primary MOSFETs depends on the load condition and dead time. The SS operation of leading leg switch can be achieved easily with the reflected output current. However, lagging leg operated with hard switching after certain load condition. The critical load boundary of lagging leg MOSFETs can be determined by

\[
\frac{1}{2} L_s I_{p-c}^2 \leq \frac{1}{2} \left( C_{S2} + C_{S3} \right) N^2.
\]

Where \( I_{p-c} \) is the critical current to be discharged the parasitic capacitors, \( C_{S2} \) and \( C_{S3} \) are the parasitic capacitors of lagging leg MOSFETs, \( S_2 \) and \( S_3 \). Above equation, it is shown that \( L_s \) is the main parameter to determine the critical load condition.

The dead time of leading and lagging leg should be enough to allow charge/discharge the parasitic capacitors and the dead time for each leg can be defined as follows:

\[
t_{\text{dead–lead}} \geq t_{d(\text{off})} + t_{r_s}.
\]

\[
t_{\text{dead–lag}} \geq t_{d(\text{off})} + t_{r_s}.
\]

Where \( t_{d(\text{off})} \) represents the turn-off delay time and \( t_{r_s} \) is the voltage rising time. For the lagging leg, the dead time should be completed before the primary current falls to zero. Otherwise, reverse resonance starts and so discharged parasitic capacitors charge again [12], [13]. Thus, ZVS turn-on of lagging leg MOSFETs is lost. Therefore, dead time optimization is also important parameter to achieve ZVS turn-on of lagging leg MOSFETs. It can be optimized according to time interval required to charge/discharge the parasitic capacitors, \( t_{\text{ZVS}} \), and the time interval allowing the primary current to fall zero, \( t_{p0} \) defined as follows:

\[
t_{\text{ZVS–lag}} \leq t_{\text{dead–lag}} \leq t_{p0}.
\]
III. PERFORMANCE COMPARISON

For the comparison study, design of each converter is evaluated based on wide range output voltage regulation and soft switching operation for the second stage of a battery charger. At the output, series connection of 14 lithium-ion battery cell is assumed for both converter. Thus, the output of the battery package has 43.4-53.9 V / 15 A with that assumption. The input of converters are fed with 385 V dc voltage obtained from a dc voltage source. The battery charge control has two modes which are constant current mode and constant voltage mode. In this work, performance of each converter is evaluated based on constant current mode with changing battery voltage. The operation analysis of the converters are performed by Matlab and obtained results are summarized in Table I.

According to obtained results, LLC resonant converter has higher transformer turns ratio compared to PSFB converter because LLC resonant converter has no lost duty ratio like it happens in PSFB converter. The increased transformer turns ratio of LLC resonant converter can help to reduce the conduction and turn-off switching loss. However, increased rms current value negatively affects the conduction loss and cost of the converter. The output voltage regulation of LLC resonant converter is provided with the switching frequency changing from 150 kHz to 200 kHz while PSFB converter provides with duty change at constant 200 kHz switching frequency.

The soft switching operation of PSFB converter depends on load condition and dead time condition. For the output voltage regulation the duty ratio is changed in constant current mode control. This results HS operation at low values of the output voltage due to extended dead time.

IV. EXPERIMENTAL RESULTS

In order to test the performance of the compared converters, two prototype are built and separately operated for 1 kW output power and 42-54 V output voltage. 385 V dc voltage is applied to the input of the converters. The component specifications and values used in built converters are given in Table II.

Fig. 4 (a) shows the measured waveforms of LLC resonant converter when output voltage is 54 V and output current is 15 A at 153 kHz. Fig. 4 (b) provides the waveforms obtained when the output is 42 V / 15 A at 200 kHz. ZVS turn-on of primary switch is achieved over wide output voltage.

The PSFB PWM converter was operated at 200 kHz switching frequency to test its performance. The SS operation of leading leg MOSFETs is usually achieved with the reflected load current to the primary side. The lagging leg MOSFETs usually have problem due to their dependence on load and dead time condition. Therefore, the measured results are given in Fig. 5 for lagging leg MOSFET’s switching. Fig. 5 (a) shows the SS operation of S2 MOSFET with 54 V / 15 A output. The converter can operate with SS until 48 V with full load due to no optimized dead time then primary switches work with HS as shown in Fig. 5 (b).

### TABLE I

**PERFORMANCE COMPARISON OF LLC RESONANT AND PSFB PWM CONVERTERS.**

<table>
<thead>
<tr>
<th>Converter Topology</th>
<th>Turns Ratio of TR, N</th>
<th>Switching Frequency Range</th>
<th>Operation of Primary MOSFETs in Constant Current Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLC Resonant DC-DC Converter</td>
<td>8</td>
<td>150-200 kHz</td>
<td>SS From 42-54V</td>
</tr>
<tr>
<td>PSFB PWM DC-DC Converter</td>
<td>6</td>
<td>200 kHz</td>
<td>HS From 42-48 V SS From 50-54 V</td>
</tr>
</tbody>
</table>

**TABLE II

**THE COMPONENTS USED IN PSFB PWM CONVERTER AND LLC RESONANT CONVERTER**

<table>
<thead>
<tr>
<th>Components</th>
<th>PSFB PWM Converter</th>
<th>LLC Resonant Converter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer</td>
<td>E/65/32/27 Np=12, Ns=2</td>
<td>E/65/32/27 Np=16, Ns=2</td>
</tr>
<tr>
<td>Snubber Components</td>
<td>L=20 µH</td>
<td>L=23.7µH, C=32.9nF, Lo=75 µH</td>
</tr>
<tr>
<td>Output Filters</td>
<td>Lo=1.1 µH, Co=12x22 µF</td>
<td>Co=12x22 µF</td>
</tr>
<tr>
<td>Primary MOSFETs S1-S4</td>
<td>C2M0080120</td>
<td></td>
</tr>
<tr>
<td>Secondary Rectifiers D1-D2</td>
<td>DSS2x101-015A</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4 The measured results of LLC resonant converter. (a) With 54 V / 15 A at 153 kHz and (b) with 42 V / 15 A at 200 kHz.
The efficiency values as a function of battery voltage were measured and obtained results are shown in Fig. 6. The obtained results show that the efficiency of PSFB PWM converter is higher than the LLC resonant converter although the soft switching feature of PSFB PWM converter is not maintained below 50 V battery voltage. Because the conduction loss of LLC resonant converter is higher due to its increased rms currents. The maximum efficiency of PSFB converter and LLC resonant converter is 94.4% and 93.6%, respectively.

V. CONCLUSIONS

In this work, soft switching operation of PSFB PWM converter and LLC resonant converter was discussed based on lithium-ion battery charge profile for on board EV battery charge applications. The operation of the converters is evaluated constant current mode and constant voltage mode of battery charger. The soft switching boundary of the primary switches are extracted theoretically and obtained results were validated experimentally. The prototype of each converter was built and tested separately for 42-54 V / 15 A output. The obtained results show that the efficiency of PSFB PWM converter is higher than the LLC resonant converter due to increased rms currents of LLC resonant converter. The maximum efficiency of PSFB converter and LLC resonant converter is 94.4% and 93.6% at full load condition, respectively.

REFERENCES


Current-Mode Rail-to Rail Instrumentation Amplifier for General Purpose Instrumentation Applications

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Abstract
Instrumentation amplifiers are used extensively in bio-potential reading, industrial sensor applications, Wheatstone bridge amplifiers etc. In this work, a high input common-mode range instrumentation amplifier is presented. The amplifier is composed of two second generation current conveyors (CCII+) with common-mode input range close to supply swings and a differential difference current conveyor (DDCC) at the second stage with high voltage swing at the output. Also an optional DC servo loop is employed as a feedback to second stage for the removal of any possible DC offset voltage at the output which can be used for AC coupled applications. The simple design strategy with high input common-mode range and nearly rail-to-rail output stage together with increased bandwidth advantage of current-mode approach makes the proposed implementation desirable for many of the general purpose instrumentation applications. The design is made using 0.35μm AMS technology with 3V supply voltage. The operation is verified by HSPICE simulations.

Keywords— current-mode circuits, biomedical instrumentation, current-conveyors, amplifier design, current-mode instrumentation amplifier.

I. INTRODUCTION
Instrumentation amplifiers are extensively used for engineering applications to amplify small differential signals. The key property of these amplifiers is the ability to reject undesired common mode voltages [1]. Therefore, Common-Mode Rejection Ratio (CMRR) is the key parameter to measure the quality of an instrumentation amplifier. Generally, voltage-mode instrument amplifiers are employed in many of the engineering applications.

Especially three op-amp instrumentation amplifier is the most popular structure among instrument amplifier topologies. [1-2]. CMRR is directly dependent on resistor matching in three op-amp configuration. Moreover, voltage-mode amplifiers are limited by gain band-width product, i.e., as the gain increases, frequency band-width decreases. An alternative is to use current-mode circuits where CMRR is not directly dependent on resistor matching. Moreover, bandwidth is not directly limited by gain in current-mode instrumentation amplifiers [3, 10-11]. The first proposed configuration of Current-Mode Instrumentation Amplifier (CMIA) implementation [4] is depicted in Fig. 1. Idealized CCII+ equations are:

\[ I_Y = 0 \]  
\[ V_X = V_Y \]  
\[ I_Z = I_X \]  

The design is made using two of the second generation current conveyors of plus type (CCII+). In the circuit, node Y is high impedance node where the input voltage is copied to low impedance node X. In the circuit of Fig. 1, differential input voltages at node Y of both conveyors are replicated at nodes X. The voltage difference of the two of the X nodes results as current at nodes of X. Then, the current flowing through X nodes is copied to node Z. Therefore the voltage at Z node is amplified by the ratio of the gain resistors of the circuit. Basic gain formula (using idealized components) of the CMIA shown in Fig. 1 is:

\[ V_{out} = \frac{R_z}{R_x} (V_{in+} - V_{in-}) \]  

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The advantage of the circuit in Fig. 1 is its simplicity, high CMRR without resistor matching and wide bandwidth. Although CMIA in Fig. 1 gives good performance without resistor matching requirements, improved configurations are proposed utilizing both outputs of the current conveyors [2, 5-7].

In this paper, two of the CCII+ elements with high input common-mode range with high output swing close to rail-to-rail swing is employed at the input stage. Then, another current conveyor, i.e. Differential Difference Current Conveyor (DDCC) is used at the second stage. So that higher CMRR performance and gain is possible. DDCC element is a rather new current conveyor element providing a variety of algebraic operations over the input ports [8]. By employing DDCC element at the second stage, variety of algebraic equations is handled easily. Moreover, an optional DC servo loop is designed for the removal of potential offset at the output which is desirable for the AC coupled instrumentation requirements. In the next section, the structure of the design together with internal structure will be explained.

II. CMIA STRUCTURE

The structure of the instrumentation amplifier is shown in Fig. 2. Two-stage amplification scheme is suitable for higher gain for the instrumentation implementation. The first stage of the amplifier is implemented using rail-to-rail CCII+ elements. The first stage implementation is critical for high CMRR which will be explained in next section. At the second stage, the difference operation of the dual outputs of the first stage is handled using DDCC element. Moreover, integration of the output is feedback from the output to the third terminal of the DDCC. The gain formulation of the system is given as:

\[
V_{X(DDCC)} = V_{Y1} - V_{Y2} + V_{Y3}, \quad (3.a)
\]

By employing DDCC element at the second stage, variety of algebraic equations is handled easily. Moreover, an optional DC servo loop is designed for the removal of potential offset at the output which is desirable for the AC coupled instrumentation requirements. In the next section, the structure of the design together with internal structure will be explained.
\[ f_{HP} = \frac{1}{2\pi \tau} = \frac{1}{2\pi R_1 C_1}. \] (5)

If the offset cancellation loop is not employed, i.e. node Y3 of the DDCC is connected to GND, the gain formulation is equal to:

\[ V_{OUT} = \frac{R_4}{R_3} \left[ \frac{2R_1}{R_2} (V_{in+} - V_{in-}) \right]. \] (6)

### III. INTERNAL BUILDING BLOCKS

The CMIA is built using CCII+ and DDCC elements. CCII+ elements are redesigned for rail-to-rail operation using a novel output biasing structure. DDCC element is also designed for rail-to-rail output swing together with precision output current mirrors to make the component operate close to idealized voltage and current equations. Basic operation principle of the CCII+ element is shown in Fig. 3. The circuit is composed of two differential blocks composed of PMOS input stage and NMOS input stage. Therefore the circuit is functional up to rail-to-rail swing. Differential blocks works as unity gain buffer cells to copy the input voltage at Y node to X node. The output transistors are biased using an output biasing circuit. Whenever any of the differential blocks is inactive, output biasing circuit still provides sufficient current drive for the output transistors M_{op} and M_{on}. Then, current at node X copied to the Z node by class AB current mirrors. The output biasing scheme for the X node output is simple so that, supply voltage is divided between the gate-to-source voltages of the four transistors as:

\[ V_{SG,OP} + V_{SG,D1} + V_{GS,D2} + V_{GS,ON} = V_{DD} \cdot V_{SS} \] (7)

Since \( V_{DD} - V_{SS} \) is 3V, there is sufficient voltage headroom for each of the transistor to operate properly. If the bias circuit does not exist in the structure, whenever

---

Fig. 3. CCII+ working principle

\[ I_{X(DDCC)} = I_{Z(DDCC)} = \frac{1}{R_1} (V_{Y1} - V_{Y2} + V_{Y3}), \] (3.b)

\[ V_{OUT} = \frac{R_4}{R_3} (V_{Y1} - V_{Y2} + V_{Y3}), \] (3.c)

\[ V_{Y1} = \frac{R_1}{R_2} (V_{in+} - V_{in-}), \] (3.d)

\[ V_{Y2} = -\frac{R_1}{R_2} (V_{in+} - V_{in-}), \] (3.e)

\[ V_{Y3} = -\frac{1}{R_1 C_1} \int V_{OUT} dt. \] (3.f)

Then output of the CMIA is,

\[ V_{OUT} = \frac{R_4}{R_3} \left[ \frac{2R_1}{R_2} (V_{in+} - V_{in-}) + \left( -\frac{1}{R_1 C_1} \int V_{OUT} dt \right) \right]. \] (4)

The integrator loop in the structure removes DC offset available at the output of the system. If the integrator loop is active, high pass cutoff frequency is:

\[ f_{HP} = \frac{1}{2\pi \tau} = \frac{1}{2\pi R_1 C_1}. \] (5)

If the offset cancellation loop is not employed, i.e. node Y3 of the DDCC is connected to GND, the gain formulation is equal to:

\[ V_{OUT} = \frac{R_4}{R_3} \left[ \frac{2R_1}{R_2} (V_{in+} - V_{in-}) \right]. \] (6)

---

Fig. 4. Circuit diagram of the CCII+
one of the driving operational trans-conductance amplifiers (OTA) are in the off state, related output transistor \( M_{O1} \) or \( M_{O2} \) gate input floats and there exists extreme current consumption at the output stage. Using the proposed scheme, both of the output transistors are active for the full swing and provide class AB operation properly. Adjustment of the output biasing can be done by sizing of the diode connected transistors \( M_{D1} \) and \( M_{D2} \). Selecting larger length \( (L) \) for the diode connected transistors limits the output biasing current which is important for low-power operation. Self-biasing scheme for driving of OTAs and output stages provides stable operation over large temperature range. Whenever bias currents of OTAs increase by temperature, bias currents \( I_{b,\text{out}} \) also increase, then quiescent drain currents \( (I_{Dr}) \) of \( M_{ON} \) and \( M_{OD} \) is limited. So that low power operation is provided over a large temperature range. Full circuit diagram with self-biasing scheme is shown in Fig. 4. Miller compensation is also employed between node X to drain of \( M_{D8} \) and node X to drain of \( M_{I} \) is also employed.

### Table I. Transistor Aspect Ratios of Fig. 4.

<table>
<thead>
<tr>
<th>Transistor</th>
<th>( W/L ) (( \mu \text{m}/\mu \text{m} ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_1 - M_2 )</td>
<td>40/2</td>
</tr>
<tr>
<td>( M_3 - M_6, M_3 - M_4 )</td>
<td>20/2</td>
</tr>
<tr>
<td>( M_6 )</td>
<td>40/4</td>
</tr>
<tr>
<td>( M_{D01} - M_{D02} )</td>
<td>30/2</td>
</tr>
<tr>
<td>( M_{ON1} - M_{ON2} )</td>
<td>20/2</td>
</tr>
<tr>
<td>( M_{B0}, M_{B4} )</td>
<td>10/2</td>
</tr>
<tr>
<td>( M_{B2}, M_{B3} )</td>
<td>3/3</td>
</tr>
<tr>
<td>( M_{B5}, M_{B6}, M_{B7}, M_{B10} )</td>
<td>40/2</td>
</tr>
<tr>
<td>( M_{B1}, M_{B9} )</td>
<td>7/2</td>
</tr>
</tbody>
</table>

As explained before, the proposed instrumentation amplifier is composed of two amplifier stages. First stage of the CMIA is based on the basic structure shown in Fig. 1. Second stage is also a differential amplifier constructed using DDCC element. DDCC element is a rather new current conveyor, providing wide variety of algebraic operations. However, DDCC element has lower common-mode range. Since common-mode voltage is mostly removed at the first stage, only residual common-mode voltage appears at the second stage. So that, DDCC element can be effectively employed at the second stage. Moreover, various input algebraic operations provide also an optional DC removal input at node Y3 as shown in Fig. 2. DC removal procedure is important especially for biopotential recordings since a low-offset voltage at the input saturates the instrumentation amplifier and prevents proper operation. So that after pre-amplification at first stage, remaining DC offset is removed using an integrator feedback loop, i.e. DC servo loop. The current-mode integrator provides grounded capacitor implementation for the integrator, which is advantageous for various implementations such as capacitance multiplication for large capacitance values, etc. The integrator is employed using a CCI\( ^{+} \) with a capacitor shown as \( C_{f} \) in Fig. 2. Filter high-pass cut-off frequency can be calculated using (5).

The internal structure of the DDCC element is shown in Fig. 5. The DDCC element is based on two equivalent differential input stage, one output stage with feedback for the output X and current copying circuit from X to Z to generate Z output. The circuit is the improved version of the DDCC proposed in [8]. The aspect ratios of the circuit are given in Table 2. In the second stage of the CMIA, i.e. DDCC circuit, a rail-to-rail input is not required since large common-mode voltage component is removed at the first stage. Here, low-voltage cascode output is employed at Z node, so that rail-to-rail output is possible with high precision the output of the proposed CMIA. Current source \( I_{b} \) is set to 2\( \mu \text{A} \) with cascode current sources in the circuit. Moreover, the circuit is operational under wide variety of current values. Bias voltages \( V_{bias1} \) and \( V_{bias2} \) are set to \( V_{DG1-1V} \) and \( V_{SS+1V} \), respectively. In the proposed scenario, desired gain is possible by adjusting the \( R_{f} \) and \( R_{t} \) resistances if \( R_{t} \) and \( R_{f} \) are internally adjusted to a constant value in Fig. 2 and using (6). DC servo loop can also be de-activated by connecting Y3 input to GND. Since X node of the DDCC is constructed using voltage followers and Z node is implemented using cascade stages, output gain can be precisely adjusted.

For DC coupled implementations, Y3 node can also be used for offset removal by removing the integrator and applying a voltage divider network at node Y3. So that a simple rail-to-rail input and output operation with precision gain and various configurations is possible using the proposed CMIA structure. Output can also be supplied by a unity gain amplifier.
IV. SIMULATION RESULTS AND DISCUSSIONS

The proposed CMIA is configured for 40 dB gain. The first stage gain is selected to be 20, the second stage gain is set to 5. Using (6), \( R_1 \) and \( R_2 \) are selected to be 5kΩ and 500kΩ, respectively. However, \( X \) nodes of the CCIIIs have non-zero resistive input impedance. Due to input resistance of \( X \) nodes, using simulations, \( R_2 \) is replaced by 485Ω. As a result the \( X \) node resistance of each CCII+ is estimated as \( (500-485) \Omega / 2 = 7.5 \Omega \). Second stage X and Z nodes of the DDCC element are close to ideal, since better output stage is designed for the DDCC element. For the second stage, \( R_3 \) and \( R_4 \) are selected as 100kΩ and 500kΩ, respectively. Capacitor \( C_f \) is selected as 1μF. Using (5) high-pass frequency for DC removal is 1.5 Hz, which is suitable for electro-cardiography (ECG) signals. The frequency response of the amplifier is shown in Fig. 6. The gain of 100 with cutoff frequency of 1.5 Hz is achieved using the given component values.

<table>
<thead>
<tr>
<th>Transistor</th>
<th>( W/L (\mu m/\mu m) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( M_1-M_4 )</td>
<td>40/4</td>
</tr>
<tr>
<td>( M_5-M_7 )</td>
<td>40/1</td>
</tr>
<tr>
<td>( M_9-M_{10} )</td>
<td>20/1</td>
</tr>
<tr>
<td>( M_{11} )</td>
<td>50/1</td>
</tr>
<tr>
<td>( M_{12}-M_{15} )</td>
<td>120/1</td>
</tr>
<tr>
<td>( M_{16}-M_{19} )</td>
<td>50/1</td>
</tr>
</tbody>
</table>

The CMRR performance of the proposed differential amplifier is dependent on two main design issues. One is dependent on device sizing; the other is related to device mismatch effects. CMRR related to device sizing do not have main impact when differential design strategy is selected [10]. Sizing effects mostly cancels out in the proposed structure, since differential design strategy cancels out common-mode effects two of the differential inputs applied to \( Y_1 \) and \( Y_2 \) nodes of the DDCC input at the second stage as the outputs from the CCII+ elements are subtracted using the second stage amplifier. If mismatch effect is not included the CMRR of the proposed structure is as high as 150 dB which is not possible in reality. By applying geometry mismatch to the differential stages of the CCII+ elements in the simulations, the CMRR is recorded as 105 dB. Therefore, matching is very critical for the pairs of \( M_1-M_2 \), \( M_3-M_4 \), \( M_5-M_6 \); and, \( M_7-M_8 \) of Fig. 4. CMRR calculation in [13, 14] also shows that if two of the differential inputs have same gain error, the common-mode effect is minimized.

Larger \( L \) values are employed for the transistors at the first stage of the CCII+ in Fig. 4, NMOS transistor lengths especially kept larger to reduce flicker noise at the first stage. As a result, 850 nV/√Hz input referred noise at 1 Hz is recorded. Noise level is reduced at higher frequencies, as expected. The results are summarized in Table 1. The CMRR recording of the proposed CMIA is comparable with the implementations in [14-16].

![Fig. 5. Internal structure of the DDCC element](image)

<table>
<thead>
<tr>
<th>Technology</th>
<th>0.35μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply</td>
<td>3 V</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>550kHz</td>
</tr>
<tr>
<td>Gain</td>
<td>40 dB (adjustable)</td>
</tr>
<tr>
<td>CMRR</td>
<td>105 dB</td>
</tr>
<tr>
<td>Input noise @ 1Hz</td>
<td>850 nV/√Hz</td>
</tr>
<tr>
<td>Input&amp;Output Swing</td>
<td>0.1V – 2.9V</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>300μW</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In this paper, a rail-to-rail CMIA circuit is designed. The circuit is designed for general purpose needs and suitable for bio-potential amplification, industrial sensor conditioning etc. The CMIA is based on two amplifier stages and DC off-set removal is possible for AC coupled implementations. The design has high CMRR, and low input referred noise compared to amplifiers without
chopper stabilization. Simplicity of the design procedure with rail-to-rail operation, easy implementation of DC offset removal are the advantages of the proposed CMIA.

REFERENCES

Measurement and Comparison of Signal Levels of GSM900, GSM1800 and UMTS Bands

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Abstract—Signal levels of GSM900, GSM1800 and UMTS bands were measured as mobile on the main streets in the city center of Diyarbakır at the same time and route during a week. The measurements were performed by using high precision and portable spectrum analyzer with an isotropic electric field antenna and a laptop. The high precision spectrum analyzer is a device that measures the high frequency electromagnetic fields. The isotropic electric field antenna allows a three axis measurements. The laptop was used to record and analyze the measurement samples. Electric field strengths were measured as signal levels in this study. Some statistical parameters such as standard deviation and variance were calculated with 95% confidence interval for measurement samples. The highest signal levels were measured as 3.8580 V/m for GSM 900 band, 2.9440 V/m for GSM1800 band and 6.0900 V/m for UMTS band during a week. Similarly, mean electric field strength values as average signal levels were calculated as 0.4985 V/m for GSM 900 band, 0.2350 V/m for GSM1800 band and 0.6281 V/m for UMTS band. According to the mean electric field strength values, the average signal levels of three bands were ranked as UMTS, GSM900 and GSM1800 from the largest to the smallest, respectively. The highest variation in standard deviation and variance was observed on Wednesday for GSM900 and UMTS bands and Thursday for GSM1800 band.

Keywords— Signal level; Electric field strength; GSM; UMTS; Statistics

I. INTRODUCTION

Advanced technological developments in mobile communication systems have influenced people's lives in many ways. Electromagnetic field (EMF) signal levels of mobile communication systems such as Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) are very important for epidemiological studies [1-3]. The effects of EMF signal levels on human health were examined by many scientific studies [4, 5]. Basic restrictions for EMF signal levels were recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [6]. Turkey has adopted the ICNIRP's reference levels for EMF exposure.

Mobile communication systems such as GSM and UMTS use different technologies. For this reason, signal levels of them may be different in the environment. GSM uses time division multiple access technology (TDMA) and frequency division multiple access technology (FDMA). The maximum output power of a radio transmitter used in GSM is 10-40 watt and frequency of power control is about 2 Hz [7]. UMTS uses code division multiple access technology (CDMA). The maximum output power of a radio transmitter used in UMTS is 20-60 watt and frequency of power control is 1500 Hz [7]. Power control and discontinuous transmission are two smart techniques [8] which are used in GSM and UMTS networks to reduce the EMF signal levels in the environment. Thus, these smart techniques enable to save the power of mobile phone and base station.

The aim of this study was to measure signal levels of GSM900, GSM1800 and UMTS bands as mobile in the city center of Diyarbakır in Turkey at the same time and route during a week. Then, signal levels of them were compared with each other and statistically analyzed. Some statistical values such as standard deviation and variance were calculated with 95% confidence interval. The average signal levels of three bands were evaluated.

II. MATERIAL AND METHOD

The measurements were performed between 10 November 2014 and 16 November 2014 as mobile on the main streets where people spend time and have fun. Communication way from base station to mobile phone is called downlink. Likewise, communication way from mobile phone to base station is called uplink. Output power of the base station is much higher than output power of the mobile phone. Therefore, downlink band was only taken into account during the measurements. Downlink frequency bands of GSM900, GSM1800 and UMTS as shown in Table 1 were measured during the whole week between 17:00 and 18:20 hours at the same route.

### TABLE I

<table>
<thead>
<tr>
<th>RF EMF Band</th>
<th>Frequency Range (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM900 DL</td>
<td>935 - 960</td>
</tr>
<tr>
<td>GSM1800 DL</td>
<td>1805 - 1880</td>
</tr>
<tr>
<td>UMTS DL</td>
<td>2110 - 2170</td>
</tr>
</tbody>
</table>

DL: Downlink
The measurement set consisted of selective radiation meter SRM-3006 (Narda Safety Test Solutions, USA) connected to isotropic antenna by a radiofrequency cable and a laptop for data collection. SRM-3006 is a high precision and portable spectrum analyzer which measures the high frequency electromagnetic fields. The isotropic antenna is the three axis electric field antenna frequency range from 27 MHz to 3 GHz, dynamic range 0.2 mV/m - 200 V/m and maximum extended measurement uncertainty +2.6/-3.8 dB for 85-2200 MHz. Cable contains ferrite to reduce the effects of the external electromagnetic fields. The isotropic antenna by a radiofrequency cable and a laptop for SRM is portable. Channel bandwidth for GSM900 [10] and GSM1800 [10] is 200 kHz, and for UMTS [11] is 5 MHz. Resolution bandwidth of SRM-3006 for GSM900 and GSM1800 was set to 50 kHz and for UMTS was set to 1000 kHz for better measurement. SRM-3006 equipped with three axis electric field antenna which was placed at 1.70 meter height above ground was mounted on the top of the car. Average speed of the car in the measurement route was about 40 km/h.

In this study, electric field strength values of three bands were chosen as measurement samples at an interval of 10 second during the mobile measurements. Then, the number of measurement samples for each EMF band was become equal to 472 samples per a day and 3304 samples per a week. The program written by us got information (e.g., latitude, longitude, the maximum instantaneous electric field strength values) from the SRM-3006 and recorded measurement samples for statistical analysis. Descriptive statistics such as standard deviation and variance were calculated with 95% confidence interval. Measurement samples were analyzed using IBM SPSS Statistics software, version 21 [12].

### III. RESULTS AND DISCUSSION

Currently, there are three mobile network operators in Turkey. GSM frequency band of two mobile network operators is 900 MHz but the other is 1800 MHz. UMTS frequency band of three mobile network operators is 2100 MHz. As seen in Table 2, Table 3 and Table 4, _10, _11, _12, _13, _14, _15, _16 denote measurement days (Monday, Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday).

<table>
<thead>
<tr>
<th>EMF band</th>
<th>N</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Sum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM900_10</td>
<td>472</td>
<td>2.8594</td>
<td>0.0316</td>
<td>2.8910</td>
<td>225.7753</td>
<td>0.478338</td>
<td>0.4312111</td>
<td>0.186</td>
</tr>
<tr>
<td>GSM900_11</td>
<td>472</td>
<td>3.0889</td>
<td>0.0321</td>
<td>3.1210</td>
<td>230.1624</td>
<td>0.487632</td>
<td>0.4306846</td>
<td>0.185</td>
</tr>
<tr>
<td>GSM900_12</td>
<td>472</td>
<td>3.8250</td>
<td>0.0331</td>
<td>3.8580</td>
<td>235.3006</td>
<td>0.498518</td>
<td>0.4636433</td>
<td>0.215</td>
</tr>
<tr>
<td>GSM900_13</td>
<td>472</td>
<td>2.1772</td>
<td>0.0308</td>
<td>2.2080</td>
<td>221.1566</td>
<td>0.468552</td>
<td>0.4148358</td>
<td>0.172</td>
</tr>
<tr>
<td>GSM900_14</td>
<td>472</td>
<td>2.4504</td>
<td>0.0336</td>
<td>2.4840</td>
<td>229.4507</td>
<td>0.486124</td>
<td>0.4238145</td>
<td>0.180</td>
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<tr>
<td>GSM900_15</td>
<td>472</td>
<td>2.8609</td>
<td>0.0342</td>
<td>2.8950</td>
<td>221.1493</td>
<td>0.468537</td>
<td>0.430354</td>
<td>0.188</td>
</tr>
<tr>
<td>GSM900_16</td>
<td>472</td>
<td>3.1351</td>
<td>0.0329</td>
<td>3.1680</td>
<td>222.0962</td>
<td>0.470543</td>
<td>0.4346786</td>
<td>0.189</td>
</tr>
</tbody>
</table>

N: number of samples  Std: Standard

<table>
<thead>
<tr>
<th>EMF band</th>
<th>N</th>
<th>Range</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Sum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM1800_10</td>
<td>472</td>
<td>1.6957</td>
<td>0.0533</td>
<td>1.7490</td>
<td>101.6694</td>
<td>0.215410</td>
<td>0.2206387</td>
<td>0.049</td>
</tr>
<tr>
<td>GSM1800_11</td>
<td>472</td>
<td>2.7386</td>
<td>0.0535</td>
<td>2.7920</td>
<td>100.0886</td>
<td>0.212052</td>
<td>0.2668446</td>
<td>0.071</td>
</tr>
<tr>
<td>GSM1800_12</td>
<td>472</td>
<td>2.6898</td>
<td>0.0532</td>
<td>2.7430</td>
<td>104.4067</td>
<td>0.221201</td>
<td>0.2548263</td>
<td>0.065</td>
</tr>
<tr>
<td>GSM1800_13</td>
<td>472</td>
<td>2.8910</td>
<td>0.0530</td>
<td>2.9440</td>
<td>110.9306</td>
<td>0.235023</td>
<td>0.2713217</td>
<td>0.074</td>
</tr>
<tr>
<td>GSM1800_14</td>
<td>472</td>
<td>1.7811</td>
<td>0.0519</td>
<td>1.8330</td>
<td>101.6694</td>
<td>0.215401</td>
<td>0.2271515</td>
<td>0.052</td>
</tr>
<tr>
<td>GSM1800_15</td>
<td>472</td>
<td>2.0164</td>
<td>0.0536</td>
<td>2.0700</td>
<td>105.7467</td>
<td>0.224040</td>
<td>0.2543026</td>
<td>0.065</td>
</tr>
<tr>
<td>GSM1800_16</td>
<td>472</td>
<td>2.1617</td>
<td>0.0524</td>
<td>2.2140</td>
<td>104.4510</td>
<td>0.221294</td>
<td>0.2443795</td>
<td>0.060</td>
</tr>
</tbody>
</table>

N: number of samples  Std: Standard
The highest variation in standard deviation and variance was observed on Thursday for GSM1800 band. The standard deviation is 0.2713217 and the variance is 0.074 as seen in Table 3.

IV. CONCLUSIONS

Signal levels of GSM900, GSM1800 and UMTS bands were measured as mobile on the main streets in the city center of Diyarbakır during a week.

In terms of the mean electric field value, it was determined that the average signal level of the UMTS band during a week was greater than the GSM900 band and the average signal level of GSM900 band was greater than GSM1800 band. The average signal levels of three bands can be listed as UMTS, GSM900 and GSM1800 from the largest to the smallest, respectively.

The highest variation in standard deviation and variance during a week was observed on Wednesday for GSM900 and UMTS bands. Furthermore, the highest variation in standard deviation and variance was determined on Thursday for GSM1800 band.

ACKNOWLEDGMENT

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REFERENCES


Design an Ultra-Wide Band Antenna for Microwave Imaging Systems

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Abstract—Microwave imaging technology has attracted many interests nowadays. This imaging system has been used in a variety of applications such as: non-destructive testing and evaluation, through-the-wall imaging, concealed weapon detection at security check points, structural health monitoring and medical imaging. Microwave imaging techniques have in recent decades experienced strong growth as a research topic in biomedical diagnostics. The basic idea of using microwave imaging system is to transmit electromagnetic waves from a transmitting antenna to the target material and receive the scattered waves at a receiving antenna. Thus, antenna choice plays an important role for the system. There is a need for compact sized, low cost and high efficiency antennas which can radiate ultra-wideband signal to transmit short pulses. Especially, ‘large bandwidth’ is vital to attain good time domain characteristics which is important for microwave imaging systems. In this study; we selected the circular patch antenna with a slot, due to their ease of fabrication, properties, small size and other advantages of microstrip technology. The schematic of the proposed antenna is presented and the dimensions are summarized in the paper. Ansoft HFSS software is used to design the proposed structure and optimize the radiation pattern and return loss. Simulation results such as directivity and return loss are given and discussed in the result part.

Keywords—Microstrip Antenna, Ultra-Wide Band Antenna, Return Loss, Microwave Imaging

I. INTRODUCTION

Microwave imaging techniques have shown excellent capabilities in various fields such as civil engineering, nondestructive testing, industrial applications, and have in recent decades experienced strong growth as a research topic in biomedical diagnostics. Many research groups throughout the world work on prototype systems for producing images of human tissues in different biomedical applications, particularly breast tumor detection [1]. The basic idea of using microwave imaging system is to transmit electromagnetic waves from a transmitting antenna to the target material and receive the scattered waves at a receiving antenna. Thus, antenna choice plays an important role.

Microwave imaging systems require certain preprocessing steps, which accept only a single polarization of the incident field as input. Also, the designed antenna must have higher gain levels together with a higher front-to-back ratio level. Furthermore, there is a need for compact sized, low cost and high efficiency antennas. Consequently, microwave imaging systems require wide-band, linearly polarized, high gain and compact antennas as their scattered field sensors [2].

For microwave imaging, researchers are interested in the 1-11 GHz frequency range because it appears to balance the conflicting demands of better spatial resolution (higher frequencies) and better penetration depth (lower frequencies) [3].

In this study; the microstrip antenna which has circular shaped patch with slot is selected due to their ease of fabrication, properties, small size and other advantages of microstrip technology. Ansoft HFSS software is used to design the proposed structure and optimize the radiation pattern and return loss.

The paper is organized as follows. In Section II, the schematic of the proposed antenna is presented and the dimensions are summarized. In Section III, simulation results are demonstrated and discussed.

II. ANTENNA DESIGN

Ultra-wideband (UWB) technology has its frequency defined in the range of 3.1 GHz to 10.6 GHz by the Federal Communication Commission (FCC) for UWB radio applications [4]. This technology has become very popular in recent years and has found widespread applications in communications landmine detection and biomedical applications. Another important application is the UWB technology in early breast cancer detection by using microwave imaging system. For this system, there is a need for compact sized, low cost and high efficiency antennas which can radiate ultra-wideband signal to transmit short pulses. Large bandwidth is vital to attain good time domain characteristics which is important for microwave imaging systems [5]. Recent research is on UWB antenna is planar technology as they are more practical in term of manufacturing and integration with the entire system.

There are several compact UWB antennas are proposed in planar technology but they exhibit omnidirectional radiation property. However, in microwave imaging system, antenna's HPBW is one of the main parameters determining the resolution; finer details can be resolved by using a narrower beam.
In this study, first omni directional planar UWB antenna is designed, then we try to improve it to directional planar UWB. The proposed antenna is a modification of the antennas given in [6], which didn’t use slot on patch.

Microstrip antennas produced with printed circuit technology includes a thin layer of low loss nonconductive material with a radiating conductive layer on one side and conductive ground layer that completely covers the non-conductive. Microstrip antennas are basically fed by the microstrip or a coaxial line. Along with technological advances, researchers have focused on different feeding structures and developed three different feeding techniques [7,8,9]. In this study a microstrip line feeding technique that is easy to design and produce is presented.

The purpose of our study is to propose an antenna which has the impedance bandwidth between 5 and 10.5 GHz for use in near field near surface imaging applications. According to this span, center frequency will be 7.5 GHz and wavelength (λ) is equal to 40 mm. For the optimum results, radius of the circular disk should be λ/4 =10 mm [10]. Also we added a slot to circular patch which has 4 mm radius and return loss graphic has been improved by using this slot. To achieve directivity in designed circular monopole antenna, generally L– shaped reflector is used. In our study, ground parameters were changed manually to obtain better results. Due to this modification, front-to-back ratio is higher than the antenna which presented in [11].

Figure 1 shows the layout view of designed circular disc monopole antenna. Dimension of ground plane is shown in figure. Width and length of microstrip line feed is 3mm and 17.2 mm respectively to match with 50Ω impedance line. Center point of slot is same with center of circular patch and diameter of circular disc is 20 mm.

As nonconductor material “FR4_epoxy” was selected for the constructed antenna, dielectric constant (εr) was taken as 4.4 and dielectric height (h) was 1.6 mm.

When simulation results are analyzed based on 10 dB return loss criterion, it was observed that the impedance bandwidth is between 5 and 10.5 GHz. At maximum operating frequency of the proposed antenna Return Loss value was obtained as -33.98 dB. RL characteristic (S11) of the antenna is presented in Figure 3.

One of the important parameters that demonstrate the antenna performance for microwave imaging is the directivity. Radiation pattern of the antenna at 7 GHz is given in Figure 4. According to pattern, front-to-back ratio is calculated 14 dB which is the good value for directivity feature. Unfortunately, it seems that there are unwanted side loop which cause to fall quality of antenna. We will try to improve this negativity and hope to obtain better radiation pattern before the operation of printing antenna on board.
Figure 4. Radiation pattern of proposed antenna at 7 GHz

IV. CONCLUSIONS

Size, directivity and a good reflection coefficient are the most important characteristics of the antenna design requirements for use in near field near surface measurement applications such as the microwave breast cancer imaging system. In this study, compact and small size of the antenna is presented. Simulation results confirm that reflection coefficient is under -10dB throughout 5-10.5 GHz. The properties of compact and UWB antennas have been ensured. Radiation pattern shows that, front-to-back ratio is 14 dB which is the good value for directivity feature. Unfortunately, it seems that there are unwanted side loop. This problem can be resolved by making some modification on ground plane.

From simulation we can conclude that circular monopole antenna is favorable for microwave imaging systems.

REFERENCES

A Simple and Efficient Approach to Compute the Operating Frequency of Annular Ring Patch Antennas by Using ANN with Bayesian Regularization Learning Algorithm

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Abstract— An annular ring patch antenna (ARPA) constructed by loading a circular slot in the center of the circular patch antenna is a popular microstrip antenna due to its favorable properties. In this paper, an application of artificial neural network (ANN) using bayesian regularization (BR) learning algorithm based on multilayer perceptron (MLP) model is presented for computing the operating frequency of annular ring ARPAs in UHF band. Firstly, the operating frequencies of 80 ARPAs having varied dimensions and electrical parameters were simulated with IE3D™ packaged software based on method of moment (MoM) in order to generate the data set for training and testing processes of the ANN model. Then ANN model was built with data set and while 70 simulated ARPAs and remaining 10 simulated ARPAs were employed for ANN model training and testing respectively. The proposed ANN model were confirmed by comparing with the suggestions reported elsewhere via measurement data published earlier in the literature. These results show that ANN model with BR learning algorithm can be successfully used to compute the operating frequency of ARPAs.

Keywords— Annular ring patch antenna, operating frequency, artificial neural network, bayesian regularization learning algorithm

I. INTRODUCTION

The wireless communication systems are also moving towards the miniaturization very rapidly [1-2]. All these requirements of today’s age wireless communication systems have led the antenna researchers to work on the various aspects of antenna designing with distinctive ideas of manufacturing and synthesis. Present portable communication and handheld devices inherently need miniaturized patch antennas (PAs). By using the substrate materials with high dielectric constant, the smaller antennas can be achieved but this gives rise to decrease the bandwidth and efficiency performances [1-2]. Thus, it is not an easy task to design a small PA managing the requirements of mobile communication devices. To cope such shortcomings of the traditional PAs, compact patch antennas (CPAs) which are formed by applying some modification such as shorting-pin/wall and slot-loading on the antenna structure, have been introduced in recent years [1]. Several slot loaded CPA configurations such as C [3], E [4-5], H [3, 6], L [7], rectangular ring [3] and annular ring [8] shapes have been presented in the literature as an alternative and effectively method to reduce the size of antenna.

Annular ring patch antennas (ARPAs) are miniaturized antenna constructed by loading a circular slot in the center of the circular patch. The size of the ARPA is substantially smaller than circular patch antenna (CPA) at the same operating frequency [8]. It can be appreciated that the average path length travelled by the current in the annular-ring patch is much longer than the corresponding circular patch for the lowest order mode [8]. Also, by choosing the inner and outer radius of the ring properly, both bandwidth broadening [8] and controlling the separation of resonant modes can be managed [9]. Due to these useful properties, it is the one of the most studied PAs. In the literature, the ARPA was theoretically investigated its resonator model in [10-13]. The mathematical tools such as vector Hankel transform, Galerkin’s method and Green functions were greatly utilized in the analysis of the ARPAs [14-19]. Methods based on cavity model and transmission line model was presented to investigate some parameters such as the operating frequency, input impedance and bandwidth [20-26]. The experimental studies concerning the ARPA were also performed to confirm the theoretical calculations in [9-10, 15-16, 26-30]. It can be seen from the literature that these methods include rigorous calculation of Hankel and Fourier transforms and Bessel functions.

Analytical methods seems to be easier but they result in accurate solutions only for regular shapes of the patch, whereas the numerical electromagnetic computation methods are suitable for all shapes of the PA. However, the numerical methods require much more time in solving Maxwell’s equations including integral and/or differential computations. So, it becomes time consuming since it repeats the same mathematical procedure even if a minor change in geometry is
carried out. On the other hand, antenna designers prefer the easier approaches without requiring much rigorous computations and consuming time.

Over a last decade artificial neural network (ANN) adopts remarkable importance in field of wireless communication due to its fast and accurate modelling, simulation, and optimization. In ANN model, we can use measured, simulated, and calculated data for training. Trained ANN model predicts accurate operating frequency for every small variation in the geometry both for thin and thick substrates. The purpose behind the training of ANN model is to minimize the error between actual output and reference output. The use of ANN in computing resonant frequency of CPAs have been proposed in [5-6].

In this study, a method of feed forward back propagation ANN (FFBP-ANN) with bayesian regularization (BR) learning algorithm [31] based on multilayered perceptron (MLP) model has been applied to compute the resonant frequencies of ARPAs. The operating frequency values of 80 ARPAs corresponding most of UHF band covering GSM, LTE, WLAN and WiMAX applications were determined by the electromagnetic simulator IE3D™ using method of moment (MoM) [32]. The simulation parameters of 70 ARPAs representing the overall problem space were used to training and the remaining 10 were then employed to test the accuracy. The results of the ANN model obtained in this study was confirmed by comparing with the measurement results published earlier in the literature [9, 10, 15, 16, 26-30].

II. ANNULAR RING PATCH ANTENNA AND SIMULATION PHASE

As shown in Fig. 1, ARPA has an annular ring patch formed by loading a circular slot with radius ai on a circular patch of radius ao on the substrate having relative dielectric constant εr overall on the ground plane.

![Fig. 1 Geometry of ARPA](image)

In order to determine the operating frequency values, the simulations were performed by means of the IE3D™ packaged software for 80 ARPAs having various parameters of antenna dimensions and dielectric constants listed in Table I. The antennas operate among 0.66 – 3.71 GHz corresponding to the UHF band.

<table>
<thead>
<tr>
<th>Number of simulations</th>
<th>Patch dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ao x ai x h x εr</td>
</tr>
<tr>
<td>4x20</td>
<td>2, 4, 6, 8, 10</td>
</tr>
<tr>
<td>15</td>
<td>3.175</td>
</tr>
<tr>
<td>20</td>
<td>3.175</td>
</tr>
<tr>
<td>25</td>
<td>3.175</td>
</tr>
<tr>
<td>30</td>
<td>3.175</td>
</tr>
</tbody>
</table>

| 5, 10, 15, 20, 25      |
| 2.2                   |
| 2.2                   |
| 2.2                   |
| 2.2                   |
| 2.2                   |

In the simulations, the antennas were supposed to a probe feed with 50 Ω. For meshing process, cell/wavelength rate values were assumed as 40 in limit of 4 GHz. The built in optimization module of the IE3D™ was utilized to determine the feed point which gives the best return loss value with the objective function S11(dB) < -10 for the operating frequencies at TM11 mode.

III. MODELING OF THE ANN FOR THE COMPUTATION THE OPERATING FREQUENCY OF ARPAS

ANN is one of the popular intelligence technique in solving engineering and mathematical problems. An ANN consists of neurons which are organized into different layers. These neurons contain non-linear type of functional, they are mutually connected by very much similar synaptic weights. During the learning process, these synaptic weights could be weakened or strengthened and therefore helping the data to be kept in the ANN. Different learning algorithms (LAs) are used for ANN networks. Some famous type of different backpropagation LAs are Levenberg Marquardt (LM), Bayesian regularization (BR), cyclical order incremental update (COIU), Powel-Beale conjugate gradient (PBCG), Fletcher-Powell conjugate gradient (FPCG), Polak-Ribiere conjugate gradient (PRCG), one step secant (OSS) and scaled conjugate gradient (SCG) [31].

In this study, the BR algorithm was used in ANN model as learning algorithm. BR learning algorithm updates the weight and bias values according to the LM optimization and minimizes a linear combination of squared errors and weights [33]. It also modifies the linear combination so that at the end of training the resulting network has good generalization qualities.
A. Training Stage of the ANN Model

The physical dimensions \((a_o, a_i, h)\) and dielectric constant values \((\varepsilon_r)\) of the simulated ARPAs were given as inputs and their respective operating frequency values of IE3D™ were given as output to the ANN model. While 70 of 80 ARPAs were employed for training phase, others 10 were used for test the models. After several trials, a hidden layer with four neurons, which yields satisfactorily results was employed. Thus, MLP ANN model having one input layer with four neurons, one hidden layer with four neurons and one output layer with one neuron was constructed, as shown in Fig. 2, where \(f_{IE3D}\) and \(f_{ANN}\) are the operating frequencies computed by IE3D™ and ANN model, respectively.

Fig. 2 The block diagram of ANN model

In the ANN model trained with BR learning algorithm, “tangent sigmoid” function was used for both input and hidden layers, whereas “purelin” function was utilized for output layer. The parameters of the ANN model used in this work are listed in Table II. The topology of the training process and calculation of average percentage error (APE) are illustrated for ANN model in Fig. 3. According to Fig. 3, the value of APE for the operating frequencies computed by the ANN model was obtained as 0.437% for the 70 ARPAs’ training data. The training results of the ANN model together with the results of IE3D™ were given in Fig. 4.

Fig. 3 The calculating of APE for ANN model

B. Testing Stage of the ANN Model

To test the performances of the ANN model constructed here, 10 simulated ARPAs whose electrical and psychical parameters listed in Table III are employed. The predicted operating frequency results and APE value of the ANN model with BR learning algorithm are tabulated in Table IV. For further comparison, the numerical results of several methods previously published in the literature [12-13, 25-26] are also listed in Table IV. It is apparent from Table IV that, the ANN model give the remarkable results in comparison with those calculated by the methods presented in the literature [12-13, 25-26].

### Table II

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of input</td>
<td>4</td>
</tr>
<tr>
<td>Number of output</td>
<td>1</td>
</tr>
<tr>
<td>Epochs</td>
<td>500</td>
</tr>
<tr>
<td>Seed value</td>
<td>662862703</td>
</tr>
<tr>
<td>Minimum gradient descent</td>
<td>(10^{-10})</td>
</tr>
<tr>
<td>Momentum parameter ((\mu))</td>
<td>0.0001</td>
</tr>
<tr>
<td>(\mu) increment</td>
<td>4</td>
</tr>
<tr>
<td>(\mu) decrement</td>
<td>0.1</td>
</tr>
<tr>
<td>Maximum (\mu)</td>
<td>(10^{10})</td>
</tr>
</tbody>
</table>

### Table III

<table>
<thead>
<tr>
<th>Antenna number</th>
<th>Patch dimensions (mm)</th>
<th>(a_o)</th>
<th>(a_i)</th>
<th>(h)</th>
<th>(\varepsilon_r)</th>
<th>(h/\lambda)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>4</td>
<td>2.5</td>
<td>9.8</td>
<td>0.045</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>6</td>
<td>1.57</td>
<td>2.33</td>
<td>0.027</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>10</td>
<td>3.175</td>
<td>2.2</td>
<td>0.056</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>3</td>
<td>0.64</td>
<td>4.5</td>
<td>0.009</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>6</td>
<td>1.57</td>
<td>2.33</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>15</td>
<td>2.5</td>
<td>9.8</td>
<td>0.027</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>25</td>
<td>4</td>
<td>3.175</td>
<td>2.2</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>12</td>
<td>1.57</td>
<td>2.33</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>30</td>
<td>10</td>
<td>0.64</td>
<td>4.5</td>
<td>0.005</td>
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<tr>
<td>10</td>
<td>30</td>
<td>20</td>
<td>3.175</td>
<td>2.2</td>
<td>0.024</td>
<td></td>
</tr>
</tbody>
</table>
10 ARPAs were utilized for the test. It was seen that computed electrical parameters of 70 ARPAs were utilized training data, simulation software based on MoM prediction of accurate operating frequency of ARPAs. IE3D™ nonlinear. The training process is once completed in a few unknown parameters in any problem including highly transformations nor rigorous expertness to determine the unknown parameters in any problem including highly nonlinearity. The training process is once completed in a few minutes by properly choosing the network parameters and the learning method, one can easily compute any parameters of interest in microseconds.

IV. CONCLUSIONS

In this paper, an application of ANN model which have been used BR learning algorithm is successfully implemented for the prediction of accurate operating frequency of ARPAs. IE3D™ simulation software based on MoM was used to define operating frequency of 80 ARPAs. ANN model, physically and electrical parameters of 70 ARPAs were utilized training data, 10 ARPAs were utilized for the test. It was seen that computed model learning with BR has been compared with those of the methods reported elsewhere [12-13, 25-26] over several measurement data of ARPAs published earlier in literature [9-10, 15-16, 26-30]. Table V gives the operating frequency values predicted with the ANN model with BR and calculated with the methods given in [12-13, 25-26], and also the their respective APE values according to the measurement parameters [9-10, 15-16, 26-30]. It should be noted that these measurement parameters were not employed for training the ANN model. As can be seen from the Table V, the methods proposed for operating frequency of the ARPA yield the comparable results, however, some calculations are in good agreement with some measured data, and others are far off. But, the operating frequency results of the ANN providing the least APE value within 1% are closer to the measurement ones for the most cases. The results achieved here show that the ANN can effectively be employed to estimate the operating frequency of ARPAs.

In order to verify the accuracy and validity for the crosscheck, the operating frequency results obtained by means of the ANN

<table>
<thead>
<tr>
<th>TABLE IV</th>
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<tbody>
<tr>
<td><strong>Operating Frequencies (GHz)</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>1.734</td>
</tr>
<tr>
<td>3.563</td>
</tr>
<tr>
<td>2.006</td>
</tr>
<tr>
<td>2.594</td>
</tr>
<tr>
<td>1.033</td>
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<tr>
<td>2.258</td>
</tr>
<tr>
<td>1.833</td>
</tr>
<tr>
<td>1.189</td>
</tr>
<tr>
<td>1.547</td>
</tr>
<tr>
<td><strong>APE (%)</strong></td>
</tr>
</tbody>
</table>

As an important matter of the fact that, although the method of ANN seems more complicated as compared to the other ones, it provides the more accurate and relatively simple way since it requires neither sophisticated functions of mathematical transformations nor rigorous expertness to determine the unknown parameters in any problem including highly nonlinearity. The training process is once completed in a few minutes by properly choosing the network parameters and the learning method, one can easily compute any parameters of interest in microseconds.

**ACKNOWLEDGMENT**

The heading of the Acknowledgment section and the References section must not be numbered.

**REFERENCES**


Control of a Three-Phase Boost Rectifier for High-Speed BLDC Generators Used in Flywheel Energy Storage System

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Abstract— There are two regions in the orbital path of the satellite such as dark and bright region. The energy is provided by solar panels in the bright region and by flywheel energy storage system (FESS) in the dark region. Brushless dc motor (BLDC) are extensively used in satellite power system as motor and generator. Also, these motors are preferred in the FESS due to the low weight, high power density, high efficiency and high speed. The voltage is obtained by BLDC motor in the generator mode and generated voltage is must be constant a value. The FESS speed and the BLDC motor phase voltage are reduced in the dark region. Therefore the voltage regulation is provided by using the boost converter in the generator mode. Boost converter is designed by using the three phase inverter which used as BLDC motor driver in the bright region. Information of the hall-effect sensors are used to the voltage regulation of BLDC generator. In this paper, sensorless control method was proposed in order to regulate the voltage of the satellite power system. The performance of the proposed method has been demonstrated by using the Matlab/SimPowerSystem blocks.

Keywords— BLDC generator, Flywheel, Energy storage, Three-phase boost rectifier

I. INTRODUCTION

FESS has been used power regulated in grid power system, electrical vehicle, satellite power system and uninterrupted power supplies in the last two decades. The FESS is preferred according to electrochemical battery in satellite power system [1]–[9]. Because, the FESS is advantages such as longer life time, bigger depth of discharge and be integrated at moment control gyroscope. The energy is provided by the FESS in the dark region. The mechanical energy is stored by the solar panels in the bright region and the stored energy is used to provide the satellite's power needs in the dark region. Another task of the solar panels is provide the energy of the satellite in the bright region.

The FESS is occurred from some mechanical parts such as flywheel, vacuumed environment, electric machinery and high speed mechanic or magnetic bearing. The magnitude of energy stored in the flywheel is proportional to the speed of flywheel. The BLDC motors are extensively used in the FESS besides industrial application such as automotive industry, medical, automation system and aircraft applications. BLDC motors are used due to high power density, low weight, high efficiency and high speed in the satellite power system [10]. The high speed BLDC motors are used as motor in charge mode and generator in discharge mode.

Three phase converters is widely used in motor drive, energy systems and other power electronic applications. Many works related to the three phase direct AC-DC boost rectifier are presented such as resistive input behavior of converter, low voltage and low power applications, boost rectifier for high-speed permanent magnet generator, energy regenerative damping [11]–[14] and optimal energy harvesting [15]. Three-phase boost rectifier topology is extensively used in low power applications.

In generator mode, the flywheel speed with the BLDC motor back-emf is decreased during the dark region time. Therefore, voltage regulation cannot achieved in power system of satellite in dark region. In this applications, voltage regulation is presented by using three-phase boost rectifier in discharge mode of the FESS.

Phase back-emf of BLDC motor is corresponded position of hall-effect sensors which used boost converter switching [16]. Phase back-emf of BLDC motor is measured to determine phase conduction order in proposed method. Therefore, sensor placement errors are eliminated with sensorless control algorithm. Lower switches of the inverter are made ON by using the BLDC motor of the phase back-emf, respectively. Upper switches of the inverter are continually made OFF and their parallel diode used as boost converter diode.

Current reference is obtained by using the DC bus voltage which measured by voltage sensor. Generator current can be controlled by using current reference. Flywheel speed and DC bus voltage is presented by using MATLAB/SimPowerSystem blocks in generator mode with conventional method and proposed method.
II. FLYWHEEL ENERGY STORAGE

Control diagram of a FESS is shown in Fig. 1 and herein motor and generator mode are determined by using voltage measurement of the solar panels. Motor current and speed is controlled by using the motor controller block in the bright region. Generator current and DC link voltage controlled by using the generator controller block in the dark region.

![Control diagram of a FESS](image)

A BLDC motor has three-phase stator windings and permanent magnet on the rotor. Switching technique of the BLDC motor is preferred as two phase conduction mode (six-step mode) due to simple switching in charge region. In this situation, the BLDC motor of voltage and moment is defined in Eq. (1) and Eq. (2), respectively.

\[ V = i_s R_s + L_s \frac{di_s}{dt} + E_z \]  
\[ T_m = T_L + J \frac{d\omega_m}{dt} + B\omega_m \]

where \( V \) is the armature voltage, \( i_s \) is the armature current, \( R_s \) is the armature resistance, \( L_s \) is the armature inductance, \( E_z \) is the back EMF voltage, \( K_s \) is the back EMF constant, \( K_s \) is the torque constant, \( T_m \) is the torque developed by the motor, \( T_L \) is the load torque, \( \omega_m \) is the angular speed, \( J \) is the moment inertia of motor and flywheel load, \( B \) is the frictional constant of motor and load.

The high speed BLDC motor has low inductance and resistance. Therefore the current ripple is too high which must be reduced. High switching frequency is required because of the high fundamental frequency are taken 500 Hz / 1 kHz. \( dv/dt \) stresses are seen on the motor winding because of high switching frequency. These voltage stresses and current ripples must be reduced by using an LC filter which transfer function is given in Eq. (3) [17].

\[ \frac{V_a}{V_i} = \frac{sC_f R_d + 1}{s^2 C_f L_f + s(C_f R_f + C_d R_d) + 1} \]  

Resonance frequency of the LC filter must be three times lower that the power converter switching frequency which taken 50 kHz. Corner frequency of the LC filter 15.93 kHz which is given in Eq. (4).

\[ f_c = \frac{1}{2\pi \sqrt{L_f C_f}} \]  

The power of satellite is provided by the flywheel energy storage while the dark region in the orbital path of the satellite. In this region, mechanical energy is transformed to the electrical energy by using the power converter. The amount of stored energy must be sufficient to provide the mechanical losses, electrical losses and mission of the satellite. The wind losses have been neglected due to space environment.

In generator mode, power of BLDC generator is given Eq. (5), where \( T_c \omega_m \) is defined as consumed power by satellite. If the Eq. (5) arranged according to the FESS, the Eq. (6) is obtained containing bearing the losses. Stored energy is obtained as shown in Eq. (7) when integral of Eq. (6) is calculated. Thus generated total energy by flywheel can be calculated by using bearing losses and needed power of satellite.

\[ J \frac{d\omega_m}{dt} \omega_m = T_c \omega_m + B\omega_m^2 \]  
\[ J \frac{d\omega_m}{dt} \omega_m = T_c \omega_m + P_b \]  
\[ E = \frac{1}{2} J(\omega_{min}^2 - \omega_{max}^2) = \int_{\omega_{min}}^{\omega_{max}} T_c \omega_m + \int_{0}^{t} P_b \]  

where \( \omega_{min} \) and \( \omega_{max} \) have been defined when FESS is designed. Calculation of the friction losses of bearing are given from Eq. (17) to Eq. (22).

\[ P_b = (M_0 + M_1)\omega_m \]  
\[ M_0 = f_0 \times (v \times n)^2 \times d_m^3 \times 10^{-10} \]  
\[ M_1 = f_1 \times P_i \times d_m \]  
\[ P_i = \omega_m (F_r + F_b) \]  
\[ F_r = m \times g \]  
\[ F_b = m_r \times e \times \omega_m^2 \]  

where \( f_0 \) and \( f_1 \) are coefficient of bearing, \( n \) is the bearing speed, \( v \) is the kinematic viscos friction of bearing grease, \( m \) is the weight of flywheel, \( m_r \) is the residual mass, \( e \) is the eccentricity between the rotational axis of the flywheel and
the mass center and \( d_a \) is the average diameter of bearing. Viscous friction of bearing grease have been not calculated due to use lean full-ceramic bearing.

### III. THREE-PHASE BOOST CONVERTER

Speed of the flywheel is reduced according to demand energy of the satellite during dark region. Therefore voltage of BLDC generator is decrease but the voltage of satellite power system must be constant a value. In generator mode, three-phase inverter and LC filter inductance are used as three-phase boost converter and boost inductor, respectively.

Figure 2 shows the general control technique of a three-phase boost rectifier. Generator current and the DC link voltage are controlled by the PI controller as shown in Fig.2. Current of BLDC generator is calculated as given in Eq. (14).

\[
I_s = \frac{I_a + I_b + I_c}{2}
\]

where \( I_a, I_b \) and \( I_c \) are current of BLDC generator phase, \( I_s \) is current of generator.

DC link voltage is measured to compare by reference voltage. Voltage controller output is obtained as reference to current controller. Upper legs of the three-phase inverter have been continually made OFF and their diodes have been used as boost converter diode. PWM has been respectively applied in lower legs by using the BLDC generator phase voltage. Conduction switch is determined by using the phase voltage in generator mode.

![Image](image.png)

**Fig. 2** The general control technique of a three-phase boost rectifier

The three-phase boost converter which used in the generator mode has been simulated by using the hall-effect sensors and the sensorless method as shown in Fig. (3). Q2, Q4 and Q6 are switched in the three-phase boost converter. Q1, Q3 and Q5 are made continually OFF.

The energy flow is performed as follow when Q2, Q4 and Q6 are made ON/OFF:

- When Q4 is turned to the ON, circuit of boost converter consist of two and two series inductors. Current flow is realized through phase-a and phase-b by following the path D1-C-D4. In this situation, the inductor energy is transferred to the DC bus capacitor and load.

![Image](image.png)

**Fig. 4** The hall-effect sensors signals and the phase voltage waveform

### IV. SIMULATION RESULTS

Phase voltage waveform of the BLDC generator was obtained by using the hall-effect sensors in conventional method.
Simulation parameters are given as follow,

\[ f_0 : 1.3; \]
\[ f_i : 0.00037; \]
\[ d_m : 18 \text{ mm}; \]
\[ m : 0.670 \text{ kg}; \]
\[ g : 9.8 \text{ m/s}^2; \]
\[ m_r^e : 10 \text{ gmm}; \]
\[ J : 0.008 \text{ kgm}^2; \]

Maxon EC-25 high-speed BLDC motor is used in simulation. Phase voltage waveform obtained by using the hall-effect sensors and phase voltage are shown in Figure (4) and Figure (5), respectively.

Q2, Q4 and Q6 are done respectively ON at the positive region of this voltage as shown in Fig. (6). Thus hall-effect sensors have been synchronized by the phase voltage of BLDC generator.

The phase voltage of BLDC generator was measured by using the star point of the LC filter capacitors in the proposed method. Positive region of the phase voltage is obtained by Eq. (15).

\[ V_{pa,ph,pc} = \frac{1}{2} \left( V_{a,b,c} + V_{a,b,c} \right) \]  \quad (15)

Peak region of the positive phase voltage was used in order to do ON lower switches. And it was obtained as shown in figure (7).

In proposed method, state of boost converter switches and phase voltages of BLDC generator are the similar to conventional method as shown in Fig. 8. Phase voltage, positive region of the phase voltage and switching sequence is shown in Fig 8, respectively.

Full ceramic bearing has been used in simulation of the FESS. The bearing losses has been calculated to obtain load.
moment of the BLDC generator. RL load resistance has been selected as the electrical load.

DC bus voltage obtained by conventional and proposed method is respectively shown in Fig (9a) and Fig (9b).

DC bus voltage remained stable in both methods despite decrease of speed of the BLDC generator.

DC bus voltage is decreased when the energy demand by satellite is bigger from the stored mechanical energy. Phase currents of BLDC generator are shown in Fig. 11 for both conventional and proposed method.

By using sensorless method, constant DC bus voltage was obtained and voltage ripple was reduced. Flywheel speed is shown in Fig (10a) and (10b) during discharge time.

DC bus voltage remained stable in both methods despite decrease of speed of the BLDC generator.

Fig. 9 DC bus voltage a) by using hall-effect sensor b) sensorless method

Fig. 10 Flywheel speed a) by using hall-effect sensor b) sensorless method

Fig. 11 Phase currents of BLDC generator. Top: Sensorless method, Bottom: By using hall-effect sensor

V. CONCLUSION

The BLDC motor is used as motor and generator in FESS which used in satellite power system. In this paper, the three-phase inverter has been used as the three-phase boost rectifier in dark region of satellite orbit.

Sensorless control method has been proposed to obtain as stable output voltage of three-phase boost rectifier. In the generator mode, generator current and DC bus voltage were controlled by using PI controller. Bearing losses and resistive load were used as generator load during discharge time of FESS. Wind losses was neglected due to vacuum environment.

Three-phase boost rectifier was performed by using Matlab/SimPowerSystem blocks for both conventional and proposed method. DC bus voltage was obtained as a constant value in both method.

Thus, hall-effect placement errors have been eliminated and DC bus voltage ripple has been reduced by using proposed method.

REFERENCES


Low Noise, High Gain, Wide Bandwidth Folded Cascode CMOS OP-AMP Based On Biasing Current Technique for ECG Signal Applications

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Abstract—this paper presents low noise, high voltage gain($\text{Av}$), and wide bandwidth($\text{GW}$) CMOS folded cascade Op-Amp. The strategy used for improving the input referred noise of the proposed CMOS operation amplifier based on maximizing the value of the small-signal transconductance ($g_{m}$) of MOSFET transistors. This strategy can be achieved using a large DC bias current. For test the operation of the proposed CMOS op-amps, Electrocardiogram (ECG) signal used as input signal with 2mV peak to peak value and 200Hz frequency. PSPICE (version 16.6) used for simulation the proposed CMOS OP-AMP with 0.18$\mu$m channel length. The simulation results with 10$\mu$A DC biasing current showed that, the value of DC power consumption is 0.296mW, the input referred noise is 67.003nV/$\sqrt{\text{Hz}}$, THE $\text{Av}$=13.6dB, 203KHz. The simulation results of the proposed CMOS op-amp with 100$\mu$A DC biasing current consumes DC power around 1.002mW and exhibits a lower input referred noise of 16.119nV/$\sqrt{\text{Hz}}$, the voltage gain is 51.4dB and $\text{GW}$ is 10MHz. The simulation results confirmed the theoretical calculations and verified very good noise performance of the proposed CMOS OP-AMP.

Index Terms—CMOS analog integrated circuit, design CMOS OP-AMP, low-noise OP-AMP, ECG signals data acquisition circuit.

I. INTRODUCTION

An instrumentation amplifier is normally and essentially employed in both portable and battery powered devices. CMOS transistor uses little power and does not produce as much heat as the traditional Bipolar Junction Transistor (BJT) [1]. The noise performance of the CMOS differential amplifier can also be due to both thermal noise and $1/f$ noise. At low frequencies, $1/f$ noise is so important whereas at high frequencies/low current thermal noise is important [2]. Several publications used to improve noise performance of CMOS OP-AMP are literature in [3, 4, 5, 6], P.K. Chan, et al, in 2000 [3] presented The strategy for minimizing the flicker noise in the folded-cascade amplifier topology and the inter-relationship of design parameters for optimum design. The proposed solution offers good tradeoff on the conflicting performance parameters such as noise, silicon area, bandwidth and power consumption. Yamu Hu, M. Sawan, in 2000 [4] described a low-noise, low-power and low voltage amplifier dedicated to very low amplitude signal acquisition from implantable electronic devices. Low noise and low DC offset are realized by means of Chopper Stabilization (CHS) technique. Reid R. Harrison, Cameron Charles, in 2003 [5] designed and tested a novel bio amplifier that uses a MOS-bipolar pseudo resistor element to amplify low-frequency signals down to the milli hertz range while rejecting large dc offsets, and they derived the theoretical inversion Pedram Mohseni, and Khalil Najafi, in 2004 [6] addressed low noise, low power fully integrated operational amplifier for a variety of biomedical neural recording applications. They demonstrated full functionality of this amplifier through in vitro measurements in saline using a polyimide sieve electrode and a micro-machined penetrating silicon probe. 4

This paper present novel strategy for improvement noise performance of folded cascode CMOS OP-AMP based on maximizing small signal transconductance ($g_{m}$) using different values of biasing current. This approach showed efficient input referred noise with acceptable range of power consumption. ECG signal as input of front end data acquisition circuit used to test the operation of the proposed folded cascode CMOS OP-AMP. Simulation results showed the excellent agreement with theoretical calculations.
II. METHODOLOGY

Our objective is the simulation and the design analysis of a high voltage gain, low noise, and low power folded cascode CMOS OP-AMP using 0.18\(\mu\)m CMOS technology so as to use it in many applications such as in Bio-potential signal acquisition systems [7].

Folded cascode CMOS operation amplifier with biasing current circuit and active stage current mirrors shown in Fig. 1. The steps that are followed in designing the folded cascode CMOS op-amp are given in [8].

The noise sources in MOSFETs include: (a) thermal noise introduced by the channel; (b) flicker noise from the channel. When a MOSFET is biased in the active region, this noise source can be represented by a current noise generator connected from the drain to source, the power spectral density PSD of this current noise generator is \(\frac{I_{\text{thermal}}^2}{2}\) which is described in the following equation [9]:

\[
I_{\text{thermal}}^2 = 4kT \frac{2}{g_m}. \tag{1}
\]

The current noise source introduced by the channel is referred back to the gate by dividing the PSD of the current noise generator by the square of the MOSFET transconductance \(g_m\). This results in an input-referred voltage noise source which is connected in series with the gate. Its approximate PSD is given as [9]

\[
V_{d,\text{thermal}}^2 = 4kT \frac{2}{g_m^2}. \tag{2}
\]

Minimizing the channel thermal noise of a MOSFET is straightforward from the above formula: the small-signal transconductance must be maximized. This can be achieved by using a large DC bias current and having a large width to length (W/L) ratio for the device [9]. Two different values of the biasing current are used to improve noise performance of the proposed folded cascode CMOS OP-AMP. Table (1) summarized the gate dimensions for MOSFETs of the proposed folded cascode CMOS OP-AMP.

<table>
<thead>
<tr>
<th>Transistor number</th>
<th>Type</th>
<th>Gate width ((\mu)m)</th>
<th>Channel length ((\mu)m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_1, M_2</td>
<td>P</td>
<td>2.7</td>
<td>0.18</td>
</tr>
<tr>
<td>M_3</td>
<td>P</td>
<td>1.95</td>
<td>0.18</td>
</tr>
<tr>
<td>M_4, M_5</td>
<td>N</td>
<td>0.58</td>
<td>0.18</td>
</tr>
<tr>
<td>M_6, M_7</td>
<td>N</td>
<td>0.58</td>
<td>0.18</td>
</tr>
<tr>
<td>M_8, M_9, M_10, M_11</td>
<td>P</td>
<td>2.7</td>
<td>0.18</td>
</tr>
</tbody>
</table>

III. SIMULATION RESULTS FOR THE PROPOSED CMOS OP-AMP

Figure (2) and figure (3) shows the frequency response (magnitude and phase) of the proposed folded cascode CMOS op-amp using biasing current equal to 10\(\mu\)A. It can be seen the value of open loop voltage gain is 13.603dB, unity gain bandwidth is 203.392KHz, and phase margin around 77.765º.
Simulation results of the input referred noise, and noise spectral density of the proposed folded cascode CMOS OP-AMP with 10µA basing current are shown in Figure (4) (a) and Figure (4)(b) respectively. We note that, the value of input referred noise is $67.003nV/\sqrt{Hz}$ and the value of spectral density is $319.62\mu V$.

Noise performance of the proposed folded cascode CMOS OP-AMP using 100µA basing current are shown in Figure 5(a) and Figure 5(b) respectively. It can be note that, when the value of basing current increased from $10\mu A$ to $100\mu A$, the value of input referred noise decreased to $16.119nV/\sqrt{Hz}$. This improvement due to maximize the value of small signal transconductance ($g_m$) of MOSFETs that inversely proportional with thermal noise of the CMOS OP-AMP.

The performance parameters for folded cascode CMOS op-amp using 100µA biasing current are obtained and compared with the performance parameters of proposed folded cascode CMOS op-amp using 10µA biasing current. This comparison is illustrated in table (2):
### TABLE 2. PERRONAMECE PARAMETERS OF THE PROPOSED CMOS OP-AMP USING TWO DIFFERENT BIASING CURRENTS

<table>
<thead>
<tr>
<th>Performance parameters</th>
<th>Folded cascade CMOS OP-AMP using basing current (100µA)</th>
<th>Folded cascade CMOS OP-AMP using basing current (10µA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>±1.8 V</td>
<td>±1.8 V</td>
</tr>
<tr>
<td>Biasing current</td>
<td>100µA</td>
<td>10µA</td>
</tr>
<tr>
<td>Gain</td>
<td>51.475 dB</td>
<td>13.603 dB</td>
</tr>
<tr>
<td>Bandwidth (GW)</td>
<td>10.453 MHz</td>
<td>203.392 KHz</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>8.6 mV/µs</td>
<td>5.48 mV/µs</td>
</tr>
<tr>
<td>Settling time</td>
<td>116.13 µs</td>
<td>179.84 µs</td>
</tr>
<tr>
<td>Power consumption</td>
<td>1.002 mW</td>
<td>0.296 mW</td>
</tr>
<tr>
<td>Input referred noise</td>
<td>16.119 nV/√Hz</td>
<td>67.003 nV/√Hz</td>
</tr>
<tr>
<td>Area</td>
<td>5.5 E-12 m²</td>
<td>0.368 E-12 m²</td>
</tr>
<tr>
<td>Signal to noise ratio</td>
<td>78.6 dB</td>
<td>91.548 dB</td>
</tr>
</tbody>
</table>

### IV. BIOMEDICAL APPLICATION (ECG SIGNAL) BASED ON THE DESIGNED CMOS OP-AMP

The ECG signal that acquired is in the range of 5µV to 8 mV. Due to the weak voltage level, the signal is fed into an amplifier circuit to be amplified to a desirable voltage level. Output from the amplifier is then fed into a bandpass filter circuit and a High Q notch filter. The purpose of this filter is to filter out the very low and high frequency noise components of the signals and the 60-Hz power line interference. The desirable analog output from the filter is then sent to S/H and ADC to become a digital signal. After that, these digital data will process in PCs or microprocessors. Figure 1 shows the proposed ECG data acquisition system [10].

Meanwhile, the recording electrodes might pick up much other unneeded interference. However, the biomedical electronics might be unable to detect small biomedical signals. Therefore, we need a high gain, accurate, and high CMRR amplifier to reduce the common mode noise and to amplify the biomedical signal only [11, 7].

For testing the designed folded cascode CMOS OP-AMP, a closed loop voltage gain of figure 7, with feedback resistor and input resistor are 500kΩ, 1kΩ are used.

![Fig. 7. Closed loop voltage gain of proposed CMOS OP-AMP with ECG as input signal](image)

A low noise and low power consumption amplifier is one of the key circuits for detecting the small level signals in the biomedical applications.

![Fig.8. ECG signal as input of the proposed CMOS OP-AMP](image)

![Fig. 9. ECG signal as output of the proposed folded cascode CMOS OP-AMP](image)
As we seen in figure (8) and Figure (9) the ECG signal with 2mV magnitude is amplified to 42mV using closed loop amplifier with the proposed folded cascode CMOS OP-AMP of figure (7). These results verified the low noise, high voltage gain operation of the designed OP-AMP.

V. CONCLUSION

CMOS op-amp with low input-referred voltage noise, low Power Spectral Density (PSD), high voltage gain, and wide gain bandwidth product GW(>1MHz) is still challenge the researchers, because of the factors like noise-aliasing and charge injection. This goal is achieved using biasing current technique (variation the bias current from 10μA to 100μA). A proposed folded cascode CMOS op-amp with PMOS input differential pair and four NMOS active load is redesigned using 0.18μm TSMC technology. The simulation results showed that, when increasing the value of biasing current of proposed CMOS OP-AMP design leads to increasing the values of small signal transconductance \( g_m \) of MOSFETs as a result the value of input referred noise is improved. Moreover, the performance parameters of the proposed OP-AMP are optimized except of power consumption is increased with acceptable range. The proposed design of CMOS operational amplifier is tested using biomedical application (ECG signal) with 2mV and 200Hz frequency as input signal. As we seen in simulation results of PSPICE program the ECG signal is amplified successfully to 42mV without distortion. Simulation results showed excellent agreement with that of theoretical calculations.

REFERENCES

Residual Lsf Vector Quantization Using Arma Prediction

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Abstract—The residual LSF vector quantization yields bit rate reduction in the vocoders. In this work, a residual LSF vector quantization obtained from Auto Regressive Moving Average (ARMA) prediction is proposed for designing codebooks at very low bit rates. This residual quantization method is applied to multi stage vector quantization method and codebooks are designed. For each codebook, the effectiveness and quality are investigated by calculating the spectral distortion and outliers. The proposed quantization method reduced the distortion without any additional complexity.

Index Terms—very low bit rate, speech processing, residual vector quantization, formant tracking, arma prediction

1. INTRODUCTION

Speech coding refers to process of reducing the bit rate of digital speech representations for transmission or storage, while maintaining a speech quality that is acceptable for the application. Most of the speech coders reported in the literature are based on linear prediction (LP) analysis [1]. For the LP based vocoders, the bit rate reduction is strongly tied to efficient quantization of the LPC filter coefficients \(\{a_i\}\). The Line Spectral Frequencies (LSF)—an equivalent representation of \(\{a_i\}\), more suitable for quantization and interpolation—can alternatively be used. In this sense, the Multi-Stage Vector Quantization (MSVQ) of LSF parameters presented in [2] has an efficient quantization performance at 22-24 bits per 20 ms frames. Furthermore, the multi stage structure has more flexibility than a single stage VQ in terms of search complexity, codebook storage and channel error protection. Very low rate speech communication systems require efficient fixed-rate and low delay coding methods which operate at lower bit rates.

Generalized vocal tract model consists of the oral tract and nasal tract. On the other hand, the linear predictive coding, which has been widely used in the speech analysis and synthesis, uses all pole type digital filters. Speech signals are assumed to be produced by filtering glottal excitation with these filters. This all pole type filter model approximates the true physical configuration of the human vocal tract, but with the nasal tract left out. The most crucial and well known shortcoming in this assumption that during any voiced pronunciation the velum is always closed and the sound wave proceeds only through the oral tract. So the influence of the nasal tract is ignored in this assumption. There is no big problem when non-nasal sounds are processed but in case of nasal sounds the mismatch of the LP model becomes severe. The zeros during nasal sounds supress the peaks in mid-frequency by flattening the spectrum there but this effect cannot easily fitted by all pole modelling. In order to include the effect of both oral and nasal tracts, it is necessary to modify all pole modelling into a pole zero modelling [3]. In order to obtain more efficient speech coding algorithms especially for transmission over noisy channels, differential quantization or predictive quantization of spectrum parameters are used. There are some pole zero modelling approaches in the literature [5-11] but they usually uses nonlinear equations or approximations. While all pole modelling is simple, pole-zero modelling requires complex nonlinear calculations. Although a pole-zero algorithm based on adaptive kalman filtering presented in [11] linearize the nonlinear components by dividing the frequency range of each formant into four bands, this nonlinear approximation method also requires too many calculations causing a complexity in the pole zero modelling.

In this work, we propose an ARMA prediction model for predictive quantization of spectrum parameters. This ARMA prediction method combines the good features of AR and MA prediction methods while eliminating their some drawbacks.

In section 2, basic formulas of MSVQ are given and then in section 2.2, residual vector quantization method using ARMA prediction is described. In section 3, designed codebook results using proposed method are presented.

2. RESIDUAL LSF QUANTIZATION

In this section, a brief description of the MSVQ method presented in [2] is outlined. The definitions presented in this section are introductory information for the residual MSVQ.

The training technique we used in designing the codebooks is the joint design technique [2]. Representative results of the residual LSF scheme with the joint design technique are presented in section 3.
2.1. Notation and Definition

The MSVQ codebooks are designed using the Generalized Lloyd Algorithm (GLA) to minimize average Weighted Mean Square Error (WMSE) based on a sufficiently rich training sequence. The training sequence is first partitioned into decision regions or cells for a given set of centroids (or codevectors). Then, for the given partitioning, the codebooks are re-optimized to minimize the distortion over the particular decision regions.

In the MSVQ system [2], the parameter vector \( x \) consisting of \( p \) LSF parameters is approximated as a quantized parameter vector \( \hat{x} \) using the minimum distortion rule

\[
\hat{x} = y_0^{(h)} + y_1^{(h)} + \ldots + y_{K-1}^{(h)}
\]

where the superscript \( n \) identifies the \( n \)th vector from the training sequence and the subscript \( r \) represents the iteration number during the training of a codebook. For details of designing a codebook in MSVQ, the reader is referred to [2].

2.2. Residual LSF vector Quantization with ARMA prediction

In the R MSVQ method, the residual LSF parameters of current frame are predicted from the quantized LSF parameters of the previous frames using interference correlation feature of spectrum parameters [5-8] and then residual LSF vectors are coded with a MSVQ codebook. Firstly, the LSF parameter vector is obtained by transforming the 10th order LPC parameter vector. Next, the average LSF vector of the training set \( x_{DC} \) is subtracted from the LSF vector \( x^{(i)} \) belonging to the \( i \)th frame. By defining mean removed LSF vectors \( \left( z^{(i)} = x^{(i)} - x_{DC} \right) \) and its quantized version \( \left( \hat{z}^{(i)} = x^{(i)} - x_{DC} \right) \), the residual LSF vector \( e^{(i)} \) is calculated using

\[
e^{(i)} = \hat{z}^{(i)} - r^{(i)}
\]

where \( i = 1, 2, \ldots \text{and} \ r^{(0)} = 0 \). The quantized residual vector \( \hat{e}^{(i)} \) is found by quantizing \( e^{(i)} \) with a VQ codebook. Depending on how \( r^{(i)} \) is computed, various prediction schemes can be proposed. If \( r^{(i)} = \alpha \left( \hat{e}^{(i-1)} + r^{(i-1)} \right) \), a first order Auto Regressive (AR(1)) predictor is obtained [5]. When \( r^{(i)} = \alpha \hat{e}^{(i-1)} \) we have a first order Moving Average (MA(1)) predictor [5]. The research in the literature have focused on these two schemes [6-8] which show that codebooks designed with using AR predictors produce lower distortion than codebooks with MA predictors, however the use of an alternative ARMA model in residual LSF prediction, which is untouched in the literature, can be more advantageous. The ARMA(1,1) predictor is

\[
r^{(i)} = \alpha_1 \hat{e}^{(i-1)} + \alpha_2 r^{(i-1)}
\]

Here, we optimize two parameters instead of one in AR(1) and MA(1) predictors. It has been observed that residual LSF codebooks designed by an ARMA(1,1) predictor have lower distortion than AR(1) and MA(1) predictor codebooks. The lowest distortion using an AR(1) model is obtained by using \( \alpha = 0.5 \). In an ARMA(1,1) predictor the lowest distortion is obtained when \( \alpha_1 = 0.3 \) and \( \alpha_2 = 0.6 \). To see the advantage of the ARMA(1,1) predictor, consider the reconstructed quantized LSF vector \( \hat{z}^{(i)} \) in the decoder

\[
\hat{z}^{(i)} = \hat{z}^{(i)} + r^{(i)}
\]

\[
= \hat{e}^{(i)} + \alpha_1 \hat{e}^{(i-1)} + \alpha_1 \alpha_2 \hat{e}^{(i-2)} + \ldots
\]

To see the advantage of the ARMA(1,1) predictor, consider the reconstructed quantized LSF vector \( \hat{z}^{(i)} \) in the decoder

\[
\hat{z}^{(i)} = \hat{z}^{(i)} + r^{(i)}
\]

\[
= \hat{e}^{(i)} + \alpha_1 \hat{e}^{(i-1)} + \alpha_1 \alpha_2 \hat{e}^{(i-2)} + \ldots
\]

\[
\alpha_1 \alpha_2 \hat{e}^{(i-3)} + \alpha_1 \alpha_2 \alpha_3 \hat{e}^{(i-4)} + \ldots
\]
which is compared to the reconstructed quantized LSF vector of the AR(1) predictor

\[ z^{(i)} = \hat{e}^{(i)} + \alpha_2 \hat{e}^{(i-1)} + \alpha_1^2 \hat{e}^{(i-2)} + \alpha_1^3 \hat{e}^{(i-3)} + \alpha_1^4 \hat{e}^{(i-4)} + \ldots \]  

(9)

It is well-known that [5] AR prediction schemes are susceptible to channel errors due to infinite memory as seen in (9). For example, for \( \alpha = 0.5 \) in AR(1), the weighting of previous quantized residuals decay like \( \{0.5, 0.25, 0.125, 0.0625, 0.0312, \ldots\} \). However, in ARMA(1,1) with \( \alpha_1 = 0.3 \) and \( \alpha_2 = 0.6 \) the weighting is \( \{0.3, 0.18, 0.108, 0.0648, 0.0388, \ldots\} \). As can be seen, the decay in ARMA(1,1) is faster which means that the susceptibility to channel errors compared to AR(1) is decreased. Hence by using an ARMA predictor not only do we reduce the distortion but also we decrease the effect of channel errors when compared to AR predictors.

![Fig. 1. Block diagram of proposed ARMA prediction](image)

Marca [7] suggested an AR predictive scheme in which prediction is performed only on every other frame which limits error propagation at most one adjacent frame. The same approach can be applied to ARMA(1,1) predictors. In practice, AR and ARMA predictive models correspond to higher order MA models as the weighting of previous quantized residuals decay to zero after a sufficiently large previous frame index, say \( p \), which means that the same spectral distortion and outlier results can be obtained by optimizing \( p \) coefficients of a MA(\( p \)) predictor. However, undue codebook design complexity would be introduced as the search is now over a \( p \) dimensional space instead of two in ARMA(1,1).

A weighted Euclidean distance measure is used for training the codebooks and during the search for the best codevector during quantization. The weighted Euclidean distance measure \( d(e, \hat{e}) \) between the input residual LSF vector \( e \) and the quantized residual LSF vector \( \hat{e} \) is given by

\[ d(e, \hat{e}) = \sum_{j=1}^{n} w_j (e_j - \hat{e}_j)^2 \]  

(10)

where \( p \) (\( p=10 \) in our case) is the number of elements in the residual LSF vector and \( w_j \) is the weight coefficients assigned to the \( j^{th} \) residual LSF vector \( (e) \).

III. PERFORMANCE EVALUATION

LPC/LSF quantization performance can be assessed using subjective tests and/or objective distortion measures. The performance of the codebooks is measured by using spectral distortion method. Hence,

\[ A(z) = 1 + \sum_{j=1}^{p} a_j z^{-j}, \quad \hat{A}(z) = 1 + \sum_{j=1}^{p} \hat{a}_j z^{-j} \]

\[ d_{SD}(A(z), \hat{A}(z)) \approx \frac{1}{n_1 - n_0} \sum_{n=n_0}^{n_1} 10 \log_{10} \frac{(\hat{A}(e^{2\pi i n/N})^2)}{(A(e^{2\pi i n/N})^2)} \]  

\[ SD = \sqrt{\frac{1}{T} \sum_{j=1}^{T} d_{SD}^2 (e^{j2\pi j/N})} \]  

(16)

where \( n_0 \) and \( n_1 \) correspond to 100 Hz and 3800 Hz respectively. \( A(z) \) is the optimal \( p^{th} \) order linear predictor and \( \hat{A}(z) \) is the predictor with quantized coefficients. \( N = 256 \) point FFT is used.

The training database (65,685 vectors) is extracted from TIMIT databases, which consists of 630 speakers of 8 major dialects of American English, each reading 10 phonetically rich sentences. The extracted database is lowpass filtered and down sampled to 8 kHz. M-L tree search procedure are used for training and testing [2] and \( M=8 \) is taken as the search depth of codevectors.

To further test the efficiency of the R_MSVQ codebook, a novel very low bit rate speech coding-decoding algorithm is designed which is described in detail in [4]. MSVQ codebooks and new residual codebooks with the same bit rate are used respectively. For each designed codebooks, the effectiveness and the limitations of codebooks are investigated by calculating the SD and percentage of outliers. For comparison purposes spectral distortion and outlier results for the codebooks designed with MSVQ and R_MSVQ algorithms are given in Table 1. For lower bit rates, there is approximately 10% bit rate reduction in the R_MSVQ scheme for identical spectral distortion values.

Listening tests and spectral distortion results for test speech data show that a three stage 22 bit/frame R_MSVQ codebook gives the same quality as the four stage 24 bit/frame MSVQ codebook in the new vocoder. We have tried to keep the bit rate of the residual LSF vector quantization as low as
possible at an acceptable level as the major contribution to the bit rate of the vocoder comes from the LSF vector quantization.

TABLE 1.

<table>
<thead>
<tr>
<th>Bits/frame</th>
<th>SD</th>
<th>[%2-4dB]</th>
<th>[%&gt;4dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[765] – 18</td>
<td>1.29</td>
<td>5.86</td>
<td>0.03</td>
</tr>
<tr>
<td>[776] – 20</td>
<td>1.17</td>
<td>3.69</td>
<td>0.03</td>
</tr>
<tr>
<td>[877] – 22</td>
<td>1.04</td>
<td>2.19</td>
<td>0.01</td>
</tr>
<tr>
<td>[888] – 24</td>
<td>0.93</td>
<td>1.28</td>
<td>0.01</td>
</tr>
</tbody>
</table>

(a) SD and outliers in LSF joint codebook design,

<table>
<thead>
<tr>
<th>Bits/frame</th>
<th>SD</th>
<th>[%2-4dB]</th>
<th>[%&gt;4dB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>[765] – 18</td>
<td>1.21</td>
<td>4.43</td>
<td>0.04</td>
</tr>
<tr>
<td>[776] – 20</td>
<td>1.10</td>
<td>2.94</td>
<td>0.02</td>
</tr>
<tr>
<td>[877] – 22</td>
<td>0.95</td>
<td>1.61</td>
<td>0.01</td>
</tr>
<tr>
<td>[888] – 24</td>
<td>0.84</td>
<td>0.75</td>
<td>0.00</td>
</tr>
</tbody>
</table>

(b) SD and outliers in residual LSF joint codebook design with ARMA prediction

REFERENCES


IV. CONCLUSIONS

This article has presented an ARMA prediction modelling approach which has been shown to produce lower distortion results. The proposed prediction algorithm improves the performance for all investigated bit rates. Furthermore, the new method has the good features of both AR and MA model. The new residual quantization method reduce the bit rate using residual LSF vectors obtained from ARMA prediction with little calculations in the algorithm. With this method error propagation is limited to a few frames for noisy channels.

It is expected that additional improvement will come with analysing of how adaptive coefficients can be found to model cepstral coefficients. Antiformant tracking here remains challenging although it has been found better results with the modelling here. On the other hand, the effectiveness of this approach is its ability to model both poles and zeros with a simple algorithm without giving nonlinear complex calculations. Further research is planning to evaluate the effectiveness of this method according to different speech databases and to find an adaptive method to adjust alfa coefficients adaptively.
A Low Cost Smartphone-Controlled Wireless Data Logger System for Monitoring of Safety-Critical Areas

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Abstract—Environment monitoring systems have gained a great attraction to maintain human health and safety in human working areas. To assure appropriate working conditions especially in safety-critical areas, wireless communication systems are mainly preferred. As a main component of such monitoring systems, wireless data loggers are required to collect, store and display sensor data at high speed, lower cost and high efficiency. This paper presents the results of a design process regarding a wireless data logger. The system is designed to detect released toxic gases along with conventional video monitoring of safety-critical areas. The system provides measurement time and date stamped sensor data onto video signal for real-time monitoring of the environment. The system also offers instant access to stored data using a mobile application through Android devices. This provides cost effective solution from end-user perspective.1

Index Terms—data logger, android, wireless communication, remote control, microcontroller

I. INTRODUCTION

Data logger is an electronic device that records several types of measurements over the time. It stores all data into memory storage and informs user at any time required. Data loggers, which use digital technologies, are commonly equipped with sensor, microcontroller, external memory, real time clock, and wireless communication module. However, structure of the data logger may be varied. Typically, data loggers work together with sensors to take input data. This data is converted to binary data and then analyzed by full-featured software to store for further processes. With emerging technologies, functionality of the data loggers has been enhanced by generic programming techniques.

Using data logger has been considered in many applications for different purposes. A survey on data logger system is presented in [1]. In [1], several studies in data logger field are reviewed. More recently, developed systems are proposed to monitor sensed data in various environment types. The works in [2-4] propose wireless data logger systems for monitoring temperature using ZigBee communication protocol. For building a wireless data logger for thermal validation systems for pharmaceutical industry is given in [5]. Another data logger system is developed for industrial cooling applications [6]. The work in [7] aims to propose a data logging system that store large numbers of data from analog signal over an extended long time. In [8], a wireless sensor network that uses data logger for a real-time air quality monitoring system is presented. The study in [9] introduces a wireless data logger system for real-time monitoring with remote control capability via PC and tablet. Although it has been successfully developed, today’s industrial market demands more cost-effective systems.

In this work, wireless data logger system is designed to monitor real-time measurements, which is the combination of sensed and video recorded data, in a specified area. Furthermore, this system enables end-users to control the stored data with all Android smartphones. Hence, it provides cost effective solution for environment monitoring system. Proposed wireless data logger system may be beneficial in detecting unsafe or hazardous conditions for human health in the working or common areas. This forms the foundation for a security system with a view to protecting human health. Besides, sensor modules that used for gas detecting are protected from external effects now that these modules are not depended on external resources. Therefore, data transmission could not be interrupted from external effects which is the another advantage of the developed data logger system.

This work is developed as an industry sponsored undergraduate project. In fact, it reports the results of the system developed by undergraduate students. All development stages of the system, such as PCB layout, software, hardware and prototyping, were completed at Atılım University laboratories.

The paper starts with describing the concept of the developed system with a block diagram as given in the next section. In section III, hardware development of data logger, software architecture, development of end-user application,
II. CONCEPT OF THE SYSTEM

The system that presented in this article comprises of three main modules which are measurement, data management and On Screen Display (OSD). The block diagram of the proposed data logger system is shown in Fig. 1.

![Block diagram of the system.](Image)

In measurement module, the amount of gases released in a specified area is measured by means of gas sensors. Measured data is gathered and stored in data management module, which is the core part of the data logger system. Since used sensors are analog sensor, an Analog-to-Digital Converter (ADC) is required to read measured data. For this purpose, the data management module first converts analog data to digital one. Then, it stamps sensed data with date and time. Data storing is the last phase of the data management module. The module is able to send data to Bluetooth module, as well. This enhances the data logger to transmit the data directly to end user. The last part of the system is OSD module which retrieves time and date stamped data in order to put them on the video signals of an area that inclined to observe. It should be noted that a wireless surveillance camera is used for the purpose of observing an area. The details of the system are given in the next section.

III. SYSTEM DEVELOPMENT

This section describes the details of proposed data logger system. First, hardware of the data logger system is discussed and then, software architecture of developed system is explained. In the third part, design process of android application for end-users is described. In the last part, system implementation is presented.

A. Data Logger Structure

As discussed in Section II, the system has three main parts. In the first part, measurement module, two types of gas sensors, MQ-4 and MQ-7, are chosen to use for gas detecting as usual, in that these sensors have an ability to obtain wide range of measurements, from temperature to carbon dioxide. After selecting gas sensors, an ADC converter is required to read binary data. Due to the fact that low power consumption and flexible connectivity applications play important role in measurement systems, a 16-bit Microcontroller Unit (MCU) is chosen which contains 8-bit ADC. Digitalized sensor data are stamped with date and time by using Real Time Clock (RTC) that is connected to MCU with I2C (Inter-Integrated Circuit) protocol. Another connection with MCU is Bluetooth module. To access into MCU from Bluetooth module, UART (Universal Asynchronous Receiver/Transmitter) protocol is used. Bluetooth modules are designed to address the needs of new wireless applications. In this work, Bluetooth module enables end-users to control the stored data through a developed application for smartphones. It works on the baud rate of 9600 and has approximately the range of 12 meter. In the last stage of data management module, data is stored in a Multi Media Card (MMC) which is connected to MCU with Serial Peripheral Interface (SPI) protocol as it provides synchronous data transmission.

OSD module is the last part of the system contains another MCU for retrieving data from data management module. To provide data transmission between management module and OSD, a RF (Radio Frequency) transmitter in management module and a RF receiver in OSD module are used. Both RF modules use ISM (Industrial, Scientific and Medical)-433 MHz band. These RF modules work on the baud rate of 600 and have approximately 300 meter outdoor range. In OSD module, MCU is connected to a single-channel monochrome OSD generator (MAX7456). It is used to create on-screen menus and other video overlays. It is NTSC and PAL compatible and displays up to 16 rows × 30 characters. SPI protocol is utilized for maintaining data transmission from MCU to OSD generator. The main working principle of OSD generator is overlaying received data from MCU onto video signals recorded by a wireless surveillance camera. As a consequence, the security monitor is linked to output of the OSD generator for displaying real-time recordings with date and time stamped sensor data. The whole system is represented in Fig. 2.

![The whole picture of the hardware development.](Image)
B. Software Architecture

Since the core part of the system is MCU, data loggers require full-featured software to improve accuracy. In MCU programming, assembly language is generally utilized. However, writing assembly code is not an easy task. For this reason, high level programming languages are proposed to make complex programming to simpler. Although high level programming languages having increasing popularity, C programming language is still most useful language for MCU programming. In this work, MicroC, which provides best solution for developing C code, is chosen as a compiler for MCU in order to adapt the developed system to currently emerging technologies.

As discussed in previous section, MMC card is connected to MCU for data storage. Yet, in MMC card, there is not any special file system like FAT16 (File Allocation Table 16) or NTFS (New Technology File System). Accordingly, data is written to the sectors of the MMC card. A library, which is provided by MicroC compiler for MCU, is utilized for sector writing. Thus, written data on the sectors of the MMC card is inaccessible by the third person. This contributes to the system as a critical feature.

Software development is initiated with writing simple code tasks. With the passage of time, term by term, improvements on students’ programming skills have been observed. They have gained an ability to complete given code writing tasks, transfer them into the MCU, and carry out simulations. Main steps of the proposed data logger software are depicted in Fig. 3.

C. End-User Application

It is widely known that Android is an open and free software stack and it powers millions of mobile devices. This gives rise to select Android platform as a software application for designed data logger system. Application is developed with Eclipse program. Developed Android application has two main features. One of them is “Send Time and Date” function where the users set time and date in the main panel, and application will send request to data logger. User interface of setting time and date is shown in Fig. 4.

Once user request is transmitted to data logger through the Bluetooth module, which provides two-way communication between the application and the logger, stored data in MMC will be sent back to the end-user application as a response. The main panel of the application and received data log is shown in Fig. 5.
The other feature of the application is “Old Records” that lists the former requests of the end-users and corresponding responses from data logger. It can also send these logs to users as e-mail or SMS (Short Message Service) at any time needed. Fig. 6 shows the recorded requests and responded data logs.

15:35-13-4-2014-Temperature: 028 Humidity: 05:
15:35-13-4-2014-Temperature: 024 Humidity: 03:
15:36-13-4-2014-Temperature: 025 Humidity: 03:
15:37-13-4-2014-Temperature: 028 Humidity: 04:
15:37-13-4-2014-Temperature: 033 Humidity: 08:

Fig. 6 Recorded data logs in the application

At last, developed application enables instant access to data from the smart phones through the Android application where the end-user can control the stored data by requesting time and date.

D. System Implementation

After designing the proposed wireless data logger system, it is implemented for real-time environment monitoring. Two type of gases, propane and carbon dioxide, considered as harmful for human health, are selected to detect. Before testing phase, a wireless surveillance camera is deployed in an area. A security monitor (LCD) is connected to OSD module to observe real-time gas measurement with surveillance camera recordings. The picture captured from the security monitor is shown in Fig. 7.

![Monitoring on LCD](image)

Fig. 7 Monitoring on LCD

IV. CONCLUSIONS

In this work, a wireless data logger system that monitors real-time environmental data is designed as an undergraduate research project. Considering human health and safety, the system can detect released toxic gases in working places. It also merges time and date stamped sensor data with surveillance records for real-time monitoring. Thus, propagation of toxic gases can be prevented by using developed wireless data logger system. Moreover, an Android application is developed for the data logger system using Eclipse software. Hence, the sensed environmental data can be accessed and controlled by smartphones. The system enables end-users to run data through the system without using wireless remote controller or control unit. This provides low cost solution and instant inquiry transaction.

As a result, it is expected that presented wireless data logger system could fulfill industrial demands. In this context, it can be adapted to various applications such as mining, defense and agriculture system applications. Therefore, in future, the system that is presented in this article may be developed for commercial purposes.

ACKNOWLEDGMENT

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High Gain, Directional and Triple Band Rectangular Microstrip Array Antenna Design

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Abstract—in this study, used in GSM1800, Wi-Fi and WiMAX applications, high gain microstrip line feed 2 x 1 patch array antenna design work was done. Antenna simulation of this antenna design made using HFSS 3D gain and directivity characteristics were simulated. Since antenna impedance is greater than line impedance, impedance matching has been made with inset – fed microstrip line and the quarter-wave transformer. The results show that the proposed antenna parameters are sufficient for GSM1800, Wi-Fi and WiMAX applications.

Keywords—2x1 linear array antenna; gain; directivity; microstrip antennas; GSM1800; Wi-Fi; WiMAX.

I. INTRODUCTION

As a result of advances in wireless systems in new generation communications and increasing demand for wireless applications promoted the significance of low profile, integrated and high gain antenna designs. Microstrip antennas used in wireless network services, satellite and missile navigation, radar systems, biomedical field and in diverse applications have a seamless record in providing for these requirements [1]. There are studies that attempt to improve Microstrip antennas by selection of special conductors and modification of geometric structures (array of antennas) because of their disadvantages such as low gain and narrow bandwidth. Microstrip antennas produced with printed circuit technology includes a thin layer of low loss insulator material with a radiating conductive layer on one side and conductive ground layer that completely covers the non-conductive. Microstrip antennas are basically fed by the microstrip or a coaxial line. Along with technological advances, researchers have focused on different feeding structures and developed three different feeding techniques [2, 3, 4]. Several factors play a role in feeding technique selection. The most significant of these is the effective transfer of antenna power between the feed line and radiation structure with the feeding technique. This occurs thanks to impedance compliance between the layers. Unwanted radiation could cause increases in side lobe level and cross polarization amplitude in radiation diagram due to impedance discord [2]. In the present study, a microstrip line feeding technique that is easy to design and produce is presented. Due to certain planar shortages of microstrip line feeding [5], an inset fed microstrip antenna was designed. The side radiating microstrip inset fed antenna is presented in Figure 1.

Various different methods were developed to analyze microstrip antennas. The most popular models among these is transmission line model, cavity model and full-wave model. Although transmission line model is the simplest method among analysis methods, it is proficient in analyzing the physical structure. However, its accuracy is lower than the other methods and it is inadequate in modeling multilayer structures. When compared to transmission line model, cavity model has a better accuracy, however it also entails a complex structure. In addition, the cavity model is effective in physical analysis similar to the transmission line model, but this model is also not adequate for modeling multilayer structures. Full-wave model is the most accurate model among these methods. However, this model is quite complex and has low capability for physical analysis [6]. The present antenna model was designed with transmission line model. Application interface
displayed in Figure 2 was developed in NetBeans IDE 8.0.2 editor [7] using JAVA programming language.

Fig. 2 Transmission Line Mode developed using JAVA

Microstrip antennas usually have low gain. In some cases, a singular antenna could not provide the desired requirements (e.g. gain, shifting the radiation to the desired direction). Thus, to improve the performance of the antenna, an array of antennae that are formed by placing more than one antennas geometrically are utilized [2 – 8]. Due to simplicity of design and their geometrical structures, microstrip antennas are one of the most frequently used antenna arrays [9]. Each component of an antenna array could be selected from elements with different structures, but to calculate the total radiation pattern of the array, similar elements are preferred. To obtain a radiation pattern in the desired direction, radiation emitted from each antenna should be added to each other in the desired direction and should eliminate one another in undesired directions. Demand for multi-frequency antenna terminals that have the capacity to receive multiple services provided by different wireless technology networks today is increasing along with the available high gain antennas. In the present study, GSM1800 technology that contains 1.8GHz GSM frequency, Wi-Fi that contains 2.4GHz ISM frequency, and WiMAX that contains 2.9GHz ISM frequency were referenced [8].

II. ANTENNA ARRAY DESIGN

Theoretical calculations were calculated based on the transmission model. Since numerical values obtained with theoretical calculations and obtained simulation results were not at the desired level, certain parameters were changed manually to obtain adequate results. For simulation findings, High Frequency Structure Simulator (HFSS) [10] based on full-wave finite elements method and widely used in the analysis of electromagnetic structures was utilized. As insulator material “Rogers Ultralam1217™” was selected for the constructed antenna and dielectric constant ($\varepsilon_r$) was taken as 2.17, dielectric thickness ($t$) was 0.035 mm and dielectric height ($h$) was 3.175 mm. Central frequency of the antenna was designed as 2.45GHz and physical parameters were calculated using equations 1 - 6 used in the transmission line model [1 – 11] and exhibited below.

\[ W = c \sqrt{\frac{(\varepsilon_r + 1)}{2}} / 2 f_0 \]  

(1)

\[ L = \left[ \frac{c}{2 f_0 \sqrt{\varepsilon_r}} \right] - 2 \]  

(2)

\[ \varepsilon_e = \left[ \frac{\varepsilon_r + 1}{2} \right] + \left[ \frac{\varepsilon_r - 1}{2} \right] \sqrt{1 + \frac{12 h}{W}} \]  

(3)

\[ \Delta L = 0.412 h \left( \frac{\varepsilon_r + 0.3}{\varepsilon_r - 0.258} \right) \left( \frac{W}{h} + 0.264 \right) \left( \frac{W}{h} + 0.8 \right) \]  

(4)

\[ y_0 = \frac{L}{(\pi)} \arccos \left( \frac{R_\text{in}}{R_\text{in0}} \right) \]  

\[ x_0 = \frac{c}{\sqrt{2 \varepsilon_{\text{eff}}}} \frac{4.65 \times 10^{-12}}{f_0} \]  

(5)

(6)

Rectangular microstrip feed antenna input and output parameters are given in Table 1 below:

<table>
<thead>
<tr>
<th>TABLE I RECTANGULAR MICROSTRIP FEED ANTENNA INPUT AND OUTPUT PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inputs</strong></td>
</tr>
<tr>
<td>Solution Frequency ($f_0$)</td>
</tr>
<tr>
<td>Substrate Thickness ($h$)</td>
</tr>
<tr>
<td>Loss Tangent ($\tan\delta$)</td>
</tr>
<tr>
<td>Dielectric Constant ($\varepsilon_r$)</td>
</tr>
<tr>
<td>Conductor thickness ($t$)</td>
</tr>
<tr>
<td>Patch Width ($W$)</td>
</tr>
<tr>
<td>Patch Length ($L$)</td>
</tr>
<tr>
<td>Microstrip Line Width ($W_f$)</td>
</tr>
<tr>
<td>Inset Distance ($y_0$)</td>
</tr>
<tr>
<td>Inset/Notch Gap ($x_0$)</td>
</tr>
<tr>
<td><strong>Micro strip line impedance (Zin)</strong></td>
</tr>
</tbody>
</table>

Where $\varepsilon_r$ is the dielectric constant for the insulator material used in the designed antenna, $\varepsilon_e$ is the effective value of the insulator material, $c$ is the speed of light, $f_0$ is the resonance frequency, $h$ is the height of the insulator material and $\Delta L$ is the line expansion. $W_f$ depicts the width of the feed line, $y_0$ depicts the position of the feeding point, $x_0$ depicts the space between the feeding point and the patch, $R_{in0}$ depicts the antenna input impedance before the feed was added, and $R_{in}$ depicts the target input impedance. In general applications, antenna input impedance is selected as 50Ω. Microstrip antenna obtained with transmission line model was multiplied to create a 2 x 1 antenna array. Microstrip lines where
Radiating patches were connected in the 2 x 1 antenna array were designed to contain a 50Ω input port. During the connection of the designed patches, input impedance of each antenna was selected as 100Ω, and quarter-wave transformer was used for input port connection. Presentation of three-band and 2-element antenna array with HFSS is given in Figure 3.

Fig. 3 Three-band and 2-element antenna array with HFSS

For microstrip transmission line shown in Figure 4, the equation of the impedance that would be measured at ℓ distance from the load impedance is shown in Equation 7.

\[ Z_0 = Z_1 \frac{Z_L + jZ_L \tan \beta \ell}{Z_L + jZ_L \tan \beta \ell} \quad (7) \]

\[ \beta = \frac{2\pi}{\lambda} \] used in the formula is the wave count.

Transformation from 100Ω to 50Ω was provided by 70Ω quarter wavelength lines. It is known that feed of an antenna separately is an adequate method to obtain best results. However, due to reasons such as practical difficulties and cost, instead of using separate sources, it was aimed to stimulate more than one antenna element with the power generated at a central resource. The structure of the 2 x 1 antenna array is presented in Figure 5. Thus, it was aimed to create a dual (2 x 1) antenna array by connecting radiating antennas adequately with microstrip lines.

Fig. 5 The structure of the 2 x 1 antenna array

One of the parameters that affect the antenna performance or demonstrate the performance quality is the return loss [12]. Acceptable return loss (RL) in antennas criterion value is -10 dB. [13]

III. EXPERIMENTAL RESULTS

In the present study, the proposed antenna was tested with HFSS simulation software. RL characteristic (S11) of the single-element antenna is presented in Figure 6 and RL characteristic of the proposed antenna is given in Figure 7.

Fig. 6. RL characteristic (S11) of the single-element antenna

Fig. 7. RL characteristic (S11) of the proposed antenna

When simulation results are analyzed based on 10 dB return loss criterion, it was observed that the maximum radiation of proposed antenna was primarily in 2.45GHz central frequency and in 1.8GHz and 2.9GHz frequencies. At central operating frequency of the proposed antenna VSWR value was obtained as 0.43dB RL -31.98dB. It was also
observed that simulation results were consistent in (RL ≥ -10dB) and (VSWR ≤ 2) interval. One of the important parameters that demonstrate the antenna performance is the gain. Antenna gain (G) given in Equation 8 is defined as a factor represented by antenna direction (D) and radiation efficiency (e) [14].

\[ G = e \times D \]  

Eq. (8)

3D gain and directionality graphs for the proposed antenna in 1.8GHz, 2.45GHz and 2.9GHz frequencies is presented in Figure 8.

![3D gain graph](image1)

![Directionality graph](image2)

Fig. 8. 3D gain (top) and directionality (bottom) graphs for the proposed antenna

Analysis of the above graphs shows that the main lobe was at the direction of z-axis, maximum gain was 10.09dB and maximum directionality was 10.14dB. The difference in gain was due to the imperfection of the utilized dielectric insulator material. Since loss tangent of the material was 0.0009, it caused a loss, albeit small. Antenna output values at the end of the simulation are given in Table 2 below.

<table>
<thead>
<tr>
<th>Antenna No</th>
<th>S11 (dB)</th>
<th>Directivity (dB)</th>
<th>Gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>-15.78</td>
<td>8.03</td>
<td>7.93</td>
</tr>
<tr>
<td>2x1 Array</td>
<td>-31.98</td>
<td>10.14</td>
<td>10.09</td>
</tr>
</tbody>
</table>

Radiation patterns of the single-element antenna and 2 x 1 antenna array are given in Figures 9 and 10, respectively. Graphics demonstrate that antenna array radiated in the same direction at mostly angles and the side lobe levels narrowed.

IV. CONCLUSIONS

In the present study, a 2x1 antenna array suitable for GSM1800, Wi-Fi and WiMAX applications [15-16], with a central frequency of 2.45GHz and 10dB directionality was designed and simulation values were presented. The small-sized and high gain microstrip antenna had a suitable structure for the communication devices used today. S-parameters of the developed antenna array demonstrate that it could serve as a multi-frequency (GSM1800+Wi-Fi+WiMAX) functional antenna when adjusted for communication systems that operate in GSM1800, Wi-Fi, WiMAX bandwidths in outdoors.

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Proposal and Analysis of a New Spectrum Sensing Algorithm for Cognitive Radio Driven Hospitals

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Abstract— Wireless technology is the key technology to eliminate the dense wire ropes from hospitals and far access to medical devices. In order to overcome the problem of bandwidth scarcity, cognitive radio driven hospitals are introduced and devices are divided in two categories. The first category is primary devices and the second one is secondary devices. Primary devices have very high priority and their communication is vital for the hospital and patients, so that no interference should be made with such devices. Secondary devices are the ones which have lower priority and they can wait until the primary devices do their communication and then, they begin to use the allocated spectrum. One of the key functions to assure that there will be no interference is a reliable spectrum sensing method. This method should be a simple one to be able to implement it in the secondary devices. Among all the sensing methods, energy detection (ED) based spectrum sensing is very popular. In order to improve the performance of ED, double threshold ED (DTED) method is introduced in literature. In this paper, a new algorithm is intruded for DTED considering previous sensing period results in detection procedure by using a memory stick. Memoryful DTED (MDTED) improves the performance of DTED considerably by only the cost of delay in secondary devices communication which has less value than the improvement of the detection method performance.

Keywords— wireless technology hospitals, cognitive radio driven hospitals, spectrum sensing, energy detection, double threshold energy detection, memory.

I. INTRODUCTION

It has been a long while that biomedical and e-health experts are trying to use wireless technologies in their field. The main purpose of this matter, instead of eliminating the dense wire ropes from the hospital environment, is to provide access from distance to the devices in the environment [1]. To meet this requirement, the number of wireless technology based hospitals grow so fast that after a while the problems began to appear. One of the most important problems was the scarcity of bandwidth. The bandwidth of the medical wireless communication is limited because of static requey allocation which is done by governmental and non-governmental commissions. In united states, the responsibility of spectrum allocation is with Federal Communications Commission (FCC). In order to mitigate the scarcity of the spectrum, cognitive radio driven hospitals (CogMed) are introduced by researchers [2].

In this cognitive radio driven hospitals, devices are categorized as primary and secondary devices. Primary devices are the ones that are vital and have higher priority to have communication. Secondary devices are the ones which have low priority and they can wait until the frequency band get vacant. So that, primary devices should not be interference by other devices as their data are so valuable. In cognitive radio technology, the secondary users sense the bandwidth and in the case of vacancy, the begin communication, otherwise, they wait for predetermined moment and sense the frequency band again [1]. There are many sensing algorithms including ED, matched filtering, wavelet based detection, cyclostationary detection [8] and covariance based detection [7] methods with their different required parameters, advantages and disadvantages. For instance, cyclostationary sensing methods needs the data about the cyclic frequency of the primary user and in matched filter sensing method, the waveform information is needed [4]. As mentioned before, each sensing method has its own advantages and disadvantages that makes them unique in their kind, but in practice, the most important factor is the simplicity of the used method. Among all the methods mentioned, ED method is the most simplest one to use in devices. ED method is based on comparison of the energy of collected samples with a threshold calculated before [3] – [5]. In order to improve the performance of ED sensing method, cooperative sensing method and DTED are introduced in literature [6]. Cooperative ED spectrum sensing is not practical solution for CogMed as there are many devices and in the case that each device use multiple sensing nodes, too complicated and busy environment will be the result of this process. The second solution is using double threshold instead of single one. In double threshold the detection is made comparison of the energy of the signal with two pre-calculated thresholds [4]. This process has improved the performance of ED method considerably, but for CogMed usage, as the inter symbol interference (ISI) with primary users could cost somebodies life, the performance should be much higher with little additional computational complexity. In this paper we recommend to use memory for the secondary user devices, so that, in the detection procedure, they could consider the result of the previous sensing period. By MTD, in the case of any error in the sensing period, the previously gathered information will help the algorithm to check the status of the channel previously.
The rest of the paper is organized as follows. In section II, the system model, ED method and some background information are provided. In section III, DTED and MTDTE methods are introduced. In Section IV simulation results and analysis is done, followed by concluding remarks in section V.

II. ENERGY DETECTION, SYSTEM MODEL AND BACKGROUND

The spectrum procedure in cognitive radio secondary medical devices is a binary hypothesis. Hypothesis $H_0$ is the condition which the primary user is having a data transfer and in the case of beginning communication, interference will occur. Hypothesis $H_1$ is when the primary user doesn’t use the spectrum and secondary user can use the spectrum [9]. These two hypothesis can be shown as follow:

$$y(t) = \begin{cases} \eta(t) : H_0, \\ h(t)x(t) + \eta(t) : H_1 \end{cases}$$ (1)

where $y(t)$ is the received signal by secondary user, $x(t)$ is the signal used for primary user, $h$ is the communication channel gain and $\eta(t)$ is additive white Gaussian noise (AWGN) which is assumed to be stationary process that satisfy $E(\eta(t))=0$ and $\text{Var}(\eta(t))=\sigma^2_\eta$ [4]. Nakagami-m fading distribution is the most used distribution in real life communication wireless channels. This model can be presented as below:

$$P_r = \frac{2m^m}{\Gamma(m)} \frac{x^{m-1}}{\sigma^2_\eta} \exp\left(-\frac{mx^2}{\sigma^2_\eta}\right), \quad m \geq \frac{1}{2}, \quad x \geq 0$$ (2)

$$\Gamma(m) = \int_0^\infty y^{m-1} e^{-y} \, dy, \quad m > 0$$ (3)

that $m$ varies based on the channel characteristics. A Rayleigh fading channel can be modelled when $m$ is equal to one and the a Gaussian channel can be modelled when $m$ goes to infinity. $\Gamma(.)$ is a gamma function.

Energy detection based spectrum sensing detector is consist of a pre-filtering system, square law device and a finite time integrator. The output of the integrator is normalized and can be shown as follow [3-5]:

$$E(t) = \frac{1}{N} \sum_{n=0}^{N-1} |x(t)|^2$$ (4)

where $N$ is the number of samples collected by the secondary user receiver. As the received signals are unknown, the gathered samples can be treated as random processes. So, the transmitted signal samples follows and independent and identically distributed (i.i.d.) random processes with mean equal to zero and variance equal to $\sigma^2_x$. The received signal $t$ noise ratio (SNR) at the detector which we show it by $\beta$ symbol from now on is equal to $\frac{|h|^2\sigma^2_x}{\sigma^2_\eta}$. Assuming the number of collected signals large enough, using central limit theorem, the probability density function (PDF) of $E(t)$ in hypothesis $H_0$ becomes a normal distribution with mean equal to $N\sigma^2_\eta$ and variance equal to $N\sigma^2_\eta$. PDF of $E(t)$ in hypothesis $H_1$ becomes a normal distribution with mean equal to $N(1+\beta)\sigma^2_\eta$ and variance equal to $(1+2\beta)N\sigma^2_\eta$. The probability that the detector detects the presence of signal under hypothesis $H_0$ is $P_d$ and the probability that the detector detects the presence of signal under hypothesis $H_1$ which is called probability of detection ($P_d$) can be shown as follow:

$$P_{d_0} = \text{prob}(E(t)> \lambda |H_0) = \Gamma(u)^{-1} \Gamma(u)$$ (5)

$$P_{d_1} = \text{prob}(E(t)> \lambda |H_1) = \frac{Q\left(\sqrt{2\beta \sqrt{\lambda}}\right)}{\sqrt{2\beta \sqrt{\lambda} \Gamma(u)^{-1} \Gamma(u)}}$$ (6)

In IEEE802.22, the $P_{d_0}$ is given but for different values, threshold based on $P_{d_0}$ which we are going to simply call it threshold can be calculated as follow:

$$\lambda_\alpha = \sigma^2_\eta \left(1 + \frac{\sqrt{2Q^{-1}P_{d_0}}}{\sqrt{\eta}}\right)$$ (7)

and the threshold based on $P_{d_1}$ at a given SNR can be shown as follow:

$$\lambda_\alpha = \sigma^2_\eta \left(1 + \frac{\sqrt{2Q^{-1}P_{d_1}}}{\sqrt{\eta}}\right)$$ (8)

Based on ED algorithm, the normalized energy of the gathered signal samples is compared with the pre-calculated threshold and in the case that the normalized energy is equal or bigger than the threshold, cognitive radio based secondary device detects the presence of the primary user and doesn’t start its communication. In the case that the normalized energy is less than the threshold, it begins its communication.

III. DOUBLE THRESHOLD ENERGY DETECTION AND MEMORYFULL DOUBLE THRESHOLD ENERGY DETECTION

DTED method is introduced in literature to improve the detecting performance of ED and make this method more reliable. By a little error, the sample energy can pass the threshold or can be less than the threshold defined. The main purpose in this sensing algorithm is defining a restricted area near threshold that contains these faulty samples and eliminate them from the detection process as they are more likely to cause an error. Restricted area constant (RAC) is shown as $\Delta$ and defined as below [6]:

$$\lambda_1 = (1-\Delta) \lambda \quad \text{As lower boundary}$$ (9)

$$\lambda_2 = (1+\Delta) \lambda \quad \text{As higher boundary}$$ (10)

In DTED algorithm, the samples are lower than $\lambda_1$ and higher than $\lambda_2$ are used for detection process. If the normalized energy of the received signals is lower than $\lambda_1$ the secondary medical device concludes that the spectrum is vacant and in the case that the received signal is higher than the value of $\lambda_2$, the decision is accuracy of it [4]. In DTED method, the probability of the energy be between boundaries in condition of hypothesis $H_0$ is shown as $P_0$ and in the case that the probability of the energy be between boundaries in condition of hypothesis $H_1$ is shown as $P_1$. $P_{d_0}$, $P_{d_1}$, $P_1$ and $P_0$ probabilities can be shown as follow:

$$P_{d_0} = \text{prob}(E(N)> \lambda_0 |H_0) = \Gamma(u)^{-1} \Gamma(u)$$ (11)

$$P_{d_1} = \text{prob}(E(N)> \lambda_1 |H_1) = Q\left(\sqrt{2\beta \sqrt{\lambda_1}}\right)$$ (12)

$$P_0 = \text{prob}(\lambda_1 < E(N) < \lambda_2 |H_0) = \left(\frac{\lambda_1}{\sqrt{2\beta \sqrt{\lambda_1}}} - \frac{\lambda_2}{\sqrt{2\beta \sqrt{\lambda_1}}}\right)$$ (13)

$$P_1 = \text{prob}(\lambda_1 < E(N) < \lambda_2 |H_1) = \left(\frac{\lambda_1}{\sqrt{2\beta \sqrt{\lambda_1}}} - \frac{\lambda_2}{\sqrt{2\beta \sqrt{\lambda_1}}}\right)$$ (14)
As mentioned earlier, reliability is the most important factor in CogMed and having multiple detectors for having cooperative detection is not possible. MDTED is a novel approach to DTED which improves the detection performance of it. This algorithm is based on saving the energy of last T previously sensed signal samples and detection is made considering these energies. Collection of T consecutive energy samples can be shown as follow:
\[ M_i(y) = \{ E(y_{i-1}), E(y_{i-2}), E(y_{i-3}), \ldots, E(y_i) \} \]

In the case that the maximum of these decision energies fall below the threshold \( \lambda_1 \) the detection process decides the hypothesis \( H_0 \) and in the case that the maximum is higher than \( \lambda_2 \) the detection process decides the hypothesis \( H_1 \). If the maximum is between \( \lambda_1 \) and \( \lambda_2 \) in any way, the next maximum value is going to be used until it doesn’t be in the restricted gap. Because of environment in real life doesn’t change rapidly and in high order by time, this method will help our detection system to not only have the results of the time, it will use previously gathered information also that will help decision process in big range. Considering the improvement of detection process performance and reliability, T-1 sensing period delays can be bearable. Also by choosing T small enough, it is possible to make the delay minimum. The algorithm of MDTED is as follow:

**Algorithm 3. MDTED spectrum sensing method**

Input : T, \( \lambda_1, \lambda_2, \sigma_i \)

Output : \( Y_i \)

1: for each sensing period do
2: for \( \zeta = 1:N \) samples do
3: if \( \lambda_0 < \text{sample energy} < \lambda_2 \) then
4: do nothing
5: else
6: \( e_i(t) \leftarrow \text{Energy of sample} \zeta, \zeta \in \{1,2,\ldots,N\} \)
7: end for
8: \( e(t) \leftarrow \text{normalized energy of the selected total} e_i(t) \) samples
9: \( M_i(y) \leftarrow \text{Energy of previous T received signals and} e(t) \)
10: \( M(t) = \text{MAX} \{ M_i(y) \} \)
11: if \( \lambda_0 < M(t) < \lambda_2 \) then
12: \( Q_i(y) = M_i(y) - M(t) \)
13: \( M(t) = \text{MAX} \{ Q_i(y) \} \)
14: end if
15: if \( M(t) < \lambda_1 \) then
16: \( Y_t \leftarrow H_0 \)
17: else
18: \( Y_t \leftarrow H_1 \)
19: return \( Y_t \)
20: end for

**P_0, P_0, P_0 and P_1 can be calculated as follow:**

\[ P_0= p(M(t) > \lambda_2 | H_0) = p(E(\gamma_i) > \lambda_2, E(\gamma_{i-1}), \ldots, E(\gamma_{i-T}) > \lambda_2 | H_0) = \]
\[ p \left( \frac{\lambda_2 - \mu_d^2}{\sqrt{2\sigma_d^2 + \sigma_i^2}} \right) T^{-1} \]

\[ P_0 = p(\lambda_1 < M(t) < \lambda_2 | H_0) = \left( \frac{\lambda_2 - \mu_d^2}{\sqrt{2\sigma_d^2 + \sigma_i^2}} \right) T^{-1} \]

**MBED detection performance is analysed and compared with DTED method in section IV.**

**IV. SIMULATION RESULTS AND ANALYSIS**

In this section the performance of DTED is studied, analysed and compared with very well-known DTED. All simulations are done in MATLAB software using QPSK modulated random signals and i.i.d. noise samples with Gaussian random variables. It is assumed that the channel doesn’t change while sampling in each sampling period. Based on IEEE 802.22, \( P_0 \) should be less or equal to 0.1 and \( P_1 \) be more than 0.9. In the simulations \( P_0 \) is chosen as 0.1 and 10^3 test signals are used and averaged. DTED and MDTED is studied with RAC equal to 0.5 and in memory section, T is equal to 2 unless it is told to be different. T equal to 2 mean the detection method needs 2 previously sensed normalized energies that should be saved in memory and be used in the detection procedure.

Figure 1 shows the performance of ED, DTED and MDTED in Gaussian channel models. Gaussian channel is the simplest channel model among all communication channel models. MBDTED with a memory equal to 2, has a much better performance compared to DTED and ED in all SNR ranges. With only saving 2 previously sensed signals energy in detection process, a high range of performance can be achieved. Unlike DTED, the performance of MBTDN doesn’t diminish suddenly in low SNRs like DTED.

**Figure 1. ED, DTED and MBDTED sensing methods performance over Gaussian channel.**

Figure 2 show the performance of ED, DTED and MBDTED in Rayleigh channel which is known as one of the worst communication channels. In this kind of channel, MBTDN again has a better performance compared to both DTED and
ED also in all SNR ranges by only the delay of 2 sensing periods.

Choosing the value of memory, based on the communication channel estimated in the cognitive radio driven hospitals and acceptable delay in the sensing procedure, we can have the best performance needed in such areas.

V. CONCLUSION

Memory based double threshold energy detection or in other words, double threshold energy detection with memory sensing algorithm is introduced in this paper. It is shown that using memory and saving the previously received signals energy in the defined algorithm can affect the sensing performance and improve the detection performance of the energy detection based spectrum sensing in very high range. DTED was defined in literature to improve the performance and reliability of ED method. We compared the MBDTED with ED and DTED methods in Gaussian and Rayleigh channels by using only 2 previously saved signals and we saw the performance of this method is much higher than both ED and DTED in wide SNR range. Disadvantage of this method is the time delay after the channel is free but considering the improvement of the sensing performance, T sensing period delay for the secondary user in order to detect the vacancy of the signal could be bearable in cognitive radio driven hospitals. Also, by choosing T and periodic sensing distance small enough, we can make the delay minimum. This research findings help to understand the effect of the memory in a sensing method and advantage and disadvantages of that which helps find optimal solutions to fulfill fundamental sensing requirements in IEEE 802.22 WRAN.

REFERENCES


Performance Evaluation for a PMSG with Interior Rotor of N35 and N42 NdFeB PMs having Same Geometry in Micro Wind Turbines

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hmamur@karatekin.edu.tr

Abstract— The aim of this paper is to compare the performance evaluation in terms of the efficiency, coggng torque and manufacturing cost for a permanent magnet synchronous generator (PMSG) with interior rotor of N35 and N42 NdFeB permanent magnets (PMs) having same geometry separately used in a micro wind turbine (MWT). Firstly N35 type PMs have been used on an interior rotor, and then its performance has been measured and calculated by a MWT setup. After that, N42 type PMs have been used on other interior rotor. According to the obtained results, the PMSG with N42 type presented better efficiency than the PMSG with N35 type. But the PMSG with N42 type has induced a bit more coggng torque than the PMSG with N35 type. When comparing in terms of efficiency, a higher efficiency has been obtained by the PMSG with N42 type.

Keywords— PMSG, PM, efficiency, NdFeB, N42, N35

I. INTRODUCTION

Nowadays, the usage of renewable energy resources such as wind, geothermal, tidal and solar in electricity production is gradually increasing. Wind energy is the most popular of these renewable energy resources. In order to convert wind energy into electrical energy, wind turbines are employed [1].

Wind turbines are divided into two classes as large wind turbines (LWTs) and small wind turbines (SWTs) [2]. While LWTs usually are operated as grid-on, SWTs are utilized as both grid-on and grid-off. Furthermore, as given in Table I, SWTs are separated into three different classes [3]. According to the power of SWTs in Table I, there are SWT types employed by direct-drive and gear mechanism systems [1].

Depending on the powers of SWTs, induction generators (IGs) and permanent magnet synchronous generators (PMSGs) are widely preferred [4]. PMSGs used SWTs are more advantageous than IGs because they have more power density, higher torque and direct-drive ability [5]. Structure of PMSG is simple and their maintenance is easy [6]. There is also no copper loss on rotor. However, one of the biggest disadvantages is their coggng torque [7]. Because of the high coggng torque, they do not commence electrical energy generation at low wind speed [2].

SWTs are designed as horizontal and vertical axis. Also, PMSGs inserted in SWTs are manufactured two types as outer and interior rotors [2, 8]. Although the PMSGs with interior rotor have more size than the PMSGs with outer rotor, their power density, moment, and efficiency are high. But, when considering in terms of manufacturing cost and labor, manufacturing cost and labor of the PMSGs with interior rotor are higher than the PMSGs with outer rotor. In addition to these, PMSGs are constructed as axial and radial flux [9-10]. Output voltage and torque of the PMSGs with radial flux are greater than the axial flux [11].

II. PERMANENT MAGNETS

Permanent magnet (PM) forms and elements that are used in PMSGs have a great impact on performance of PMSGs [12-14]. PM forms, which are placed on an interior rotor with four poles, are illustrated in Fig. 1. A surface radial, a parallel, a breadloaf and a ring PM form are presented in Fig. 1. These are classified as the PMSGs with surface PM rotor. Additionally, there are also the types of PMSG with PMs that are embedded in a rotor.

Magnetization profiles also are important during the PM usage. These are sine angle or sine direction, parallel, radial sine and radial profile. In addition, these are illustrated in Fig. 1 and the most popular of which is the parallel magnetization.

PMs are made up of Aluminium-Nickel-Cobalt (AlNiCo), Ferrite, Samarium-Cobalt (SmCo), and Neodymium-Iron-Boron (NdFeB) materials. Their operating temperatures and magnetic flux density-magnetic field intensity ($BH_{max}$) are

<table>
<thead>
<tr>
<th>Category</th>
<th>Power (kW)</th>
<th>Annual energy production (kWh)</th>
<th>Tower height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro wind turbine</td>
<td>&lt; 1.5</td>
<td>&lt; 1,000</td>
<td>10–18</td>
</tr>
<tr>
<td>Small wind turbine</td>
<td>1.5–50</td>
<td>&lt; 200,000</td>
<td>15–35</td>
</tr>
<tr>
<td>Small–medium wind turbine</td>
<td>50–500</td>
<td>&lt; 1,800,000</td>
<td>25–55</td>
</tr>
</tbody>
</table>
different from each other. The values are given in Table II. When Table II is examined carefully, although NdFeB PMs have the highest $BH_{\text{max}}$ value, their operating temperatures are lower than others. Recently, NdFeB PMs are widely preferred in PMSG design. [15-16].

The remanence magnetization value ($B_r$) of AlNiCo magnets among them is quite high. Due to the fact that they are expensive and also can easily lose their magnetization property, they are not preferred lately.

Ferrite magnets being another type of PMs that are relatively lower cost and more commonly usage than AlNiCo PMs. They are resistant to the loss of remanence magnetization. $BH_{\text{max}}$ values of both AlNiCo and Ferrite PMs are lower than SmCo and NdFeB PMs.

SmCo and NdFeB PMs are known as rare-earth magnets. Their $BH_{\text{max}}$ values are quite high compared the AlNiCo and Ferrite PMs. One of their biggest disadvantages is that they are fragile. The remanence and demagnetization values are high.

In recent years, the remanence values of the sintered NdFeB PMs are increased above 1.0 T. In Table III, properties of N35 and N45 type NdFeB PMs that are sintered at different grade are listed. Their performance analysis two type PMs were carried out in a micro wind turbine (MWT). The sintered PMs offer up to 150°C operation temperatures. After the operation temperatures, SmCo PMs are preferred. SmCo PMs also have different temperatures. Their operation temperatures rise at 250°C. Studies continue to increase the operation temperatures of NdFeB and SmCo PMs.

<table>
<thead>
<tr>
<th>Permanent Magnet</th>
<th>Operating Temperature (°C)</th>
<th>$BH_{\text{max}}$ (kJ/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NdFeB</td>
<td>150</td>
<td>470</td>
</tr>
<tr>
<td>SmCo</td>
<td>250</td>
<td>350</td>
</tr>
<tr>
<td>AlNiCo</td>
<td>500</td>
<td>80</td>
</tr>
<tr>
<td>Ferrite</td>
<td>300</td>
<td>40</td>
</tr>
</tbody>
</table>

**TABLE III**

<table>
<thead>
<tr>
<th>Properties</th>
<th>N42</th>
<th>N35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum energy production, $BH_{\text{max}}$ (kJ/m$^3$)</td>
<td>318-342</td>
<td>263-287</td>
</tr>
<tr>
<td>Maximum work temperature, $T_w$ (°C)</td>
<td>≤80</td>
<td>≤80</td>
</tr>
<tr>
<td>Remanence (residual induction), $B_r$ (T)</td>
<td>1.28-1.32</td>
<td>1.17-1.22</td>
</tr>
<tr>
<td>Coercive force, $H_c$ (kA/m)</td>
<td>≥915</td>
<td>≥868</td>
</tr>
<tr>
<td>Curie temperature, $T_c$ (°C)</td>
<td>310</td>
<td>310</td>
</tr>
<tr>
<td>Intrinsic coercive force, $H_{ic}$ (kA/m)</td>
<td>≥955</td>
<td>≥955</td>
</tr>
<tr>
<td>Temperature coefficient, $\beta H_r$ (% / °C)</td>
<td>-0.6</td>
<td>-0.6</td>
</tr>
</tbody>
</table>

**III. APPLICATION**

Two rotors with surface magnet having N35 and N42 NdFeB PMs were designed and manufactured. The dimension of PMs was sized as $20 \times 20 \times 6$ mm. The usage of the rotor together with a PMSG stator is demonstrated in Fig. 2. A designed MWT, the stator and the rotor dimensions are presented in Table IV. To reduce the cogging torque, the used PMs were selected in a breadloaf form. Moreover, to reduce the cogging torque, their placement was fulfilled according to a pole shifting method [7].

After the rotors that manufactured two prototypes had inserted in the PMSGs, they were mounted in the MWT, as given in Fig. 3. Lastly, their performance tests were carried out by means of a truck test [2]. During the truck test, the generated power from the MWT was transferred to a battery group, which was consisted of four batteries of 12 V and 60 Ah. The battery group was charged until 13.5 V. After the charge, two load resistances of 600 W were used to discharge to the battery group. In order to measure the generated power from the MWT with PMSGs used N35 and N42 NdFeB PMs, a data acquisition system, which was described and embedded formulas in detail [2], was operated. The measurement of input power of the MWT was realized by two different calibrated anemometers – one was Prova AVM-03, the other was Kestrel 3000 model. In addition to these measurements, wind speed was also checked by the truck display. The ambient temperature was registered by both the data...
TABLE IV
THE DESIGNED MWT, STATOR AND ROTOR DIMENSIONS AND PROPERTIES

<table>
<thead>
<tr>
<th>MWT</th>
<th>Stator</th>
<th>Rotor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Properties</td>
<td>Value</td>
<td>Properties</td>
</tr>
<tr>
<td>Number of blades</td>
<td>3</td>
<td>Inner diameter</td>
</tr>
<tr>
<td>Body material</td>
<td>Aluminum</td>
<td>Length</td>
</tr>
<tr>
<td>Axis type</td>
<td>HAWT</td>
<td>Groove width</td>
</tr>
<tr>
<td>Blade swept area</td>
<td>1.207 m²</td>
<td>Outer diameter</td>
</tr>
<tr>
<td>Breaking</td>
<td>Electrical</td>
<td>Slot height</td>
</tr>
<tr>
<td>Rotation</td>
<td>Clock wise</td>
<td>Slot opening width</td>
</tr>
</tbody>
</table>

acquisition system and Extect HD200 measurement instrument. To define the cogging torque, Crane Electronics/UTA-451-0020-OP 5 Nm brand/model transmitter and Crane Electronics/TO-890-01CR-0-EUR brand/model display, which was described in detail [7], were utilized.

IV. RESULTS AND DISCUSSION

The truck test was carried out by using of the PMSGs having two rotors with surface magnet separately used N35 and N42 NdFeB PMs in the MWT. The air pressure was taken as 1020 hPa to calculate the input power of the MWT. The air density was obtained 1.221 kg/m³.

In the MWT having the PMSG with the surface magnet rotor used N35 NdFeB PMs, the cut-in was measured 2.7 m/s. In other, which was the MWT having the PMSG with the surface magnet rotor used N42 NdFeB PMs, the cut-in was taken 4.1 m/s.

Depending on wind speed, the generated powers from the MWTs and their power coefficients are presented in Fig. 4 and 5. When Fig. 4 was examined, the nominal power of the MWT that has N35 NdFeB PMs at 11 m/s wind speed was 177 W. Also, the nominal power of the MWT that has N42 NdFeB PMs at 11 m/s wind speed was 210 W. In Fig. 5, the power coefficients of the MWTs having N35 and N42 NdFeB
PMs were defined 0.277 and 0.388, respectively.

The highest cogging torques of the MWTs having N35 and N42 NdFeB PMs were measured as 0.1 Nm and 0.17 Nm, respectively, as shown in Fig. 6. In the MWT with N42 NdFeB PMs, the cogging torque was occurred a quite high value. In order to reduce the value, it is necessary that other cogging torque reduction methods have to be used together with the pole shifting method.

When examining the literature regarding the study, Lee et al. [8] executed a study with outer rotor PMSG. The cogging torque of about 0.18 Nm was measured in their application used PMs of Br 0.43 T. Also, Jang et al. [10] manufactured an MWT of 1.5 kW employed both NdFeB of 1.26 T and Ferrite type PMs. They tried on the usability of Ferrite PM instead of NdFeB PM. Although the PMSGs generated same power, the PMSG with Ferrite type PM had larger volume than the PMSG with NdFeB PM in reference to their results. They saw an increase of manufacturing cost. At low speed conditions, Ani et al. [17] compared six different SWT in terms of the energy yield and the generated electricity cost. Their cut-in speeds were observed between 2.5 and 4.0 m/s. The manufactured MWT with N35 type PM was compared with regard to cut in, manufacturing cost, energy yield and generated electricity cost in [2] in detail. Because of the usage of N42 type PMs, a small increase of 20 € occurred in the manufacturing cost of MWT. The value was below 1%. According these obtained results, these were quite acceptable when the carried out study was compared the other studies in literature.

**V. CONCLUSIONS**

In this study, the performance analyses of both N35 and N42 type PMs for interior rotor PMSGs were carried out. For this purpose, two surface-mounted rotors that had N35 and N42 NdFeB PMs were designed and manufactured. These were tried on an MWT with PMSG inserted in the rotors separately. According to the obtained data, the generated nominal power of the MWT having N35 NdFeB PMs was obtained 177 W. For the other MWT having N42 NdFeB PMs, the generated nominal power was measured 210 W. When compared their power coefficients, an improvement of 18% was calculated in the MWT having N42 NdFeB PMs in reference to the MWT having N35 NdFeB PMs. However, the cogging torque increased 1.7 times in the MWT having N42 NdFeB PMs. On the other hand, the usage N42 NdFeB PMs increased only 1% in the manufacturing cost of MWT.

**ACKNOWLEDGMENT**

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Observer Design for the Hodgkin-Huxley Neuronal Model

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Abstract—Hodgkin-Huxley (HH) neuronal model has been widely accepted neuronal model in neuroscience. The variation of the ionic currents in neuron cell causes the variations in the membrane potential. The level of membrane potential indicates the activation and inactivation dynamics. In this paper, in order to observe the unmeasurable states and parameters of HH neuron accurately, Runge-Kutta discretization based nonlinear observer is designed. In numerical simulations, the membrane potential is measured and the ionic currents are estimated. The numerical results provide accurate estimation results that can be used both in monitoring and control of neuron dynamics.

Keywords—Nonlinear observer, state estimation, Hodgkin-Huxley neuronal model, discretization based gradient observer, sliding-mode observer, extended Kalman filter, RMSE.

I. INTRODUCTION

Mathematical model of a biological system presents an understanding for the behavior of the system. Recently, mathematical models of the bacteria populations, diseases, microbiological organisms and nerve cells have increasing applications for biology, medicine, biomedical, neuroscience fields. In this work, we have interested on Hodgkin-Huxley neuronal model. In general, nervous systems have very complex structures with largely interconnected neuron cells. These neurons carry out the computational and communication tasks with electrical potentials. The charge ionic distribution of the neuron cell generates of the electrical potential on the membrane potential. When a membrane has enough action potential, then firing threshold can be reached then there exist spikes on the membrane voltage [1]. The communication with neighboring neurons or the information patterns stored on the neurons are occurred based on this membrane potential such that the control of the membrane potential by ionic currents is an important subject of the neuroscience and biomedical engineering.

In neuroscience, Hodgkin-Huxley (HH) model is a first introduced model of the neuron cell [2]. The mathematical model of the HH model explaining the relations between membrane potential and ion channels is experimentally constructed using the electrical behavior of the giant axon in squad. In fact, it is a five state model that are the membrane potential and four ion channel currents modeled as an electrical circuit. Based on the HH model, there are developed electrical circuits to realize its behavior and stimulate under different conditions. At the same time, in order to produce practical and implementable neuron model, different neuron models are developed based on the HH model such as namely FitzHugh Nagumo model (FHN), Morris-Lecar model, Hindmarsh-Rose model and etc. [1]. In order to analyse the behaviour of neuron models, some of models are realized using electronic components [3]-[5].

Nonlinear observers have been used for considerably amount of applications in the subject of such as state estimation, parameter estimation, fault detection and isolation, disturbance estimation, unknown input estimation and other applications. Therefore, in literature, various types of the nonlinear observers can be found for a specific application. As a leading work on state observers have been first published for linear systems [6], and then extended for nonlinear systems [7]. With the requirements on the state estimation, there have introduced several nonlinear observers such as extended-Luenberger observer [8], extended-Kalman filter [9], sliding-mode observer [10], [11], high-gain observer [12], Takagi-Sugeno fuzzy observers [13], Runge-Kutta observer [14]-[16] etc. The nonlinear observers mentioned above are based on the mathematical model of the nonlinear system.

In this study, some of nonlinear observers are chosen to estimate the states of HH neuronal model. For the HH neuronal model, the membrane potential is assumed to be measurable but the currents or auxiliary variables are assumed to unmeasurable. The aim is to estimate the unmeasurable states of the HH neuron model for an observer based future work such as in neuroscience medicine; there exist some mental diseases to treat using external stimulus of the nerve cells. The designed observers are selected purposely such that extended Kalman filter (EKF), sliding-mode observer (SMO), and discretization based gradient observer (DBGO). The chosen and designed nonlinear observers are applied to estimate the states of the HH neuron model then estimation results are plotted and root-mean squared errors (RMSE) are given in Table. As a general result, state estimation results are accurately obtained for the HH

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neural model of future applications in neuroscience, biomedical engineering and medicine.

This paper is organized as follows: In Section 2, nonlinear observers, which are designed here, are explained in detail. Section 3 presents the Hodgkin-Huxley neuron model with mathematical dynamics. The Section 4 illustrates the state estimation results of the HH neuronal model using designed nonlinear observers. The discussions about the design conditions and application results of the observers are given in Section 5.

II. NONLINEAR OBSERVERS

Consider a nth order continuous-time nonlinear multi-input multi-output (MIMO) system:

\[
\begin{align*}
\dot{x} &= f(x,u) \\
y &= g(x,u) \\
x_i(t) &\in X_i, u_i(t) \in U_i, \forall t \geq 0 (1)
\end{align*}
\]

where \( x(t) \in X \subset \mathbb{R}^n \) is the state vector, \( u(t) \in U \subset \mathbb{R}^m \) is the vector of measured control inputs and \( y(t) \in \mathbb{R}^p \) is the vector of outputs measurements. Nonlinear dynamics are subject to state and input constraints written as

\[
\begin{align*}
X_i &= \{x_i \in \mathbb{R}^n | x_{i_{\min}} \leq x_i \leq x_{i_{\max}} \} \\
U_i &= \{u_i \in \mathbb{R}^m | u_{i_{\min}} \leq u_i \leq u_{i_{\max}} \}.
\end{align*}
\]

It is assumed that the functions \( f_i \) and \( g_j \) \([i = 1, ..., N] , [j = 1, ..., Q]\) are known and continuously differentiable with respect to the control inputs and the state variables and also the state variables are not available for measurement. The problem is to get the estimates \( \hat{x}(t) \) of the unmeasured states of the system (1) by using only the available input and output measurements. The nonlinear system is given in Eq. (1) is discretized to get samples from the time instants. The Runge-Kutta (RK) discretization method is adopted for obtaining discretized models of the continuous-time nonlinear system. The states and the output values of the system which belong to the next sampling time as in compact form can be predicted as

\[
\begin{align*}
\hat{x}[n+1] &= f(\hat{x}[n], u[n]) = \hat{x}[n] + k[n] \\
\hat{y}[n] &= g(\hat{x}[n], u[n])
\end{align*}
\]

where

\[
k[n] = \sum_{i=1}^{N} \left[ \begin{array}{c}
\frac{1}{6} \left( k_{11} + 2k_{12} + 2k_{13} + k_{14} \right) \\
k_{21} + 2k_{22} + 2k_{23} + k_{24} \\
k_{31} + 2k_{32} + 2k_{33} + k_{34} \\
\vdots \\
1 \end{array} \right]
\]

\[
k_{ij} \text{ variables with } i = 1, ..., N \text{ and } j = 1, ..., N \text{ are explicitly defined as}
\]

\[
\begin{align*}
k_1 &= T_f f(\hat{x}, u) \\
k_2 &= T_f f(\hat{x} + 0.5k_1, u) \\
k_3 &= T_f f(\hat{x} + 0.5k_2, u) \\
k_4 &= T_f f(\hat{x} + k_3, u)
\end{align*}
\]

where it is called as the discretized model of the continuous-time system. For a Lipschitz nonlinear system the stability of RK discretization is shown using sufficiently small step size [17].

A. Extended Kalman Filter

The EKF uses a recursive algorithm consisting of two parts namely prediction and measurement correction [9]. Consider the following state-space model of a discretized nonlinear dynamic system of (1) the states of which are to be estimated,

\[
\begin{align*}
x[n + 1] &= f(x[n], u[n]) + w[n] \\
y[n + 1] &= g(x[n], u[n]) + v[n]
\end{align*}
\]

\[
w \sim N(0, Q) \\
v \sim N(0, R)
\]

where \( x[n] \) is a N-dimensional state vector, \( u[n] \in \mathbb{R}^k \) is the vector of input signals and \( y[n] \in \mathbb{R}^p \) is the vector of output signals. In (6), \( f(\cdot) \) is the discrete model of the nonlinear system. The random variables \( w \) and \( v \) represent the process and measurement noises, respectively, which are assumed to have independent and normal probability distributions with zero mean. Moreover, they have uncorrelated \( Q \) and \( R \) noise covariance matrices. In the measurement correction stage a posteriori state estimates \( \hat{x}[n] \) and the a posteriori error \( P[n] \) are calculated using current measurements and the observer model. Thus, error covariance of the estimator is minimized. Time update equations for prediction stage are as follows,

\[
\begin{align*}
\hat{x}[n] &= f(\hat{x}^-[n-1], u[n-1]), \\
\end{align*}
\]

Similarly, measurement update equations related to correction stage are,

\[
\begin{align*}
P^-[n] &= (1 - Y[n]H[n])P^-[n],
\end{align*}
\]

where \( \hat{x}^-[n] \) is state estimation vector, \( Y[n] \) and \( P[n] \) matrices are Kalman gain and error covariance matrices, respectively. It is assumed that the functions \( f(\cdot) \) and \( g(\cdot) \) are differentiable with respect to \( x \) and \( u \) parameters where \( A[n] \) and \( H[n] \) matrices are the Jacobian matrices as

\[
\begin{align*}
A[n] &= \frac{\partial f}{\partial x} \bigg|_{x=\hat{x}^-[n-1], u=u[n-1]} \\
H[n] &= \frac{\partial g}{\partial x} \bigg|_{x=\hat{x}^-[n-1], u=u[n-1]}
\end{align*}
\]

These matrices, which are updated at every sampling time, are used recursively in prediction and correction update equations of the EKF.

B. Sliding-Mode Observer

The sliding-mode observers are known for robustness to uncertainties and finite-time convergence properties [10], [11]. SMOs construct a sliding-motion of output estimation error between the measured system output and observer output. There are some applications of the SMOs for state and parameter estimation of nonlinear systems [18], [19]. One of the states is measured and the estimated states are corrected using measurement error in a switching function and multiplying by a feedback constant. For the state estimation of
nonlinear system (1), classical sliding-mode observer is designed as follows.

\[
\begin{align*}
\dot{x}_1[n] &= -h_1 e_m[n] + \hat{x}_2 - d_1 \text{sign}(e_m[n]), \\
\dot{x}_2[n] &= -h_2 e_m[n] + \hat{x}_3 - d_2 \text{sign}(e_m[n]), \\
\vdots & \\
\dot{x}_N[n] &= -h_N e_m[n] + \hat{f} - d_N \text{sign}(e_m[n]).
\end{align*}
\]

(10)

where \(e_m[n] = \hat{x}_m[n] - x_m[n]\) is the measurement error and \(x_m\) (\(m = 1, N\)) is the single available measurement. The function \(f(x[n], u[n])\) is an approximation of \(f(x[n], u[n])\).

For bounded input case of the nonlinear DBGO, the DBGO state updates are performed as

\[
\begin{align*}
\Delta \hat{x}[n+1] &= \hat{x}[n] + (\hat{T}[n] \alpha[n+1] + \mu) I , \\
\hat{y}[n+1] &= \hat{g}(\hat{x}[n+1], \hat{u}[n]).
\end{align*}
\]

(17)

where \(I\) is \(N \times N\) identity matrix, and change of the states is

\[
\Delta \hat{x}[n] = (\hat{T}[n] \alpha[n] + \mu) I \hat{e}[n].
\]

(18)

For bounded input case of the nonlinear DBGO, convergence was proved in [15].

III. HODGKIN-HUXLEY NEURONAL MODEL

The Hodgkin-Huxley (HH) model is a mathematical model that describes how action potentials in neurons are initiated and propagated [2]. HH model defines the electro-physiological behavior of a neuron. The interoperability of neuron’s is important for memory, calculation, motion control and diseases such as epilepsy. Also, synchronized activity and temporal correlation are fundamental tools for encoding and exchanging information for neuronal information processing in the brain [2].

It is a set of nonlinear ordinary differential equations that approximates the electrical characteristics of excitable cells. The basic single HH neuron is described by a Markov model as a set of nonlinear ODEs:

\[
\begin{align*}
C \dot{V} &= -g_N a_m h(V - V_{Na}) - g_K n^4 (V - V_K) - g_L (V - \text{in}) \\
&= a_m (V)(1 - m) - \beta_n(V) n, \\
&= a_h(V)(1 - h) - \beta_h(V) h, \\
&= a_N(V)(1 - N) - \beta_N(V) n,
\end{align*}
\]

(19)

where \(C\) is the membrane capacitance and \(V\) is the membrane potential. \(m, h, n\) are the gating variables. They represent the activation of the sodium flow current, the inactivation of the sodium flow current and activation of the potassium flow current, respectively. The spikes are generated with very low current levels. The explicit form of the functions \(a_m(V), a_h(V), a_N(V), \beta_m(V), \beta_h(V)\) and \(\beta_N(V)\), which
describes the transition rates between open and closed states of
the channels in Eq. (19), are given below:
\[ a_m(V) = 0.1(V + 40)/(1 - \exp(-(V + 40)/10)), \]
\[ \beta_m(V) = 4\exp(-(V + 65)/18), \]
\[ a_h(V) = 0.07\exp(-(V + 65)/20), \]
\[ \beta_h(V) = 1/(1 + \exp(-(V + 35)/10)), \]
\[ a_h(V) = 0.01(V + 55)/(1 - \exp(-(V + 55)/10)), \]
\[ \beta_h(V) = 0.125\exp(-(V + 65)/80), \]

The gating variables are described the probability for
appropriate gate to be open. Therefore, these variables take
values between 0 and 1, where 0 means that the gate is closed,
and 1 means that the gate is open. The parameters of the single
neuron based on the HH model are given in TABLE I.

<table>
<thead>
<tr>
<th>Table I: Model variables and parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>\beta_{Na}</td>
</tr>
<tr>
<td>\beta_K</td>
</tr>
<tr>
<td>g_L</td>
</tr>
<tr>
<td>V_{Na}</td>
</tr>
<tr>
<td>V_K</td>
</tr>
<tr>
<td>V_L</td>
</tr>
</tbody>
</table>

An example of chaotic dynamics of the HH neuronal model
is shown in Fig. 1 for initial conditions \( V = 0mV, m = 0.0529, \)
\( h = 0.5961 \) and \( n = 0.3177 \) with sampling period \( T_s = 0.01s. \)

![Fig. 1 Membrane potential \( V \) vs sodium flow current \( m \).](image)

**IV. NUMERICAL RESULTS**

In this section, the state estimation results are plotted
separately and a comparative table is shown to discuss the
estimation performances of nonlinear observers in root-mean
squared errors (RMSE). The main goal of the study is to
provide accurate state estimation results for HH neuronal model
using different nonlinear observers. At the same time, we have
chance to compare and discuss the observer’s estimation
capability. In order to get fair estimation results, the observers
are initialized with same states and the parameters observers are
tuned to get best estimation results for each designed observer.

![Fig. 2 DBG0 estimation results for Hodgkin-Huxley neuronal model.](image)

Fig 2 presents state estimation results using DBG0. The
estimation results are very accurate for all four states such that
the estimated states are rapidly converging to the real neuron
states which are promising to use for real-time control studies.
a) Membrane potential ($V$) estimate (mV)

b) Activation of the sodium flow current ($m$) estimate

c) Inactivation of the sodium flow current ($h$) estimate

d) Activation of the potassium flow current ($n$) estimate

Fig. 3 SMO estimation results for Hodgkin-Huxley neuronal model.

SMO based state estimation results are shown in Fig. 3, respectively. The estimated states are following to the real states slightly late compared to the DBGO estimation results. However, after a few milliseconds, the real states are estimated accurately. The design parameters of the SMO are determined through grid search as follows: $h_1 = 8 \times 10^{-2}$, $h_2 = 1 \times 10^{-4}$, $h_3 = 1 \times 10^{-5}$, $d_1 = 1 \times 10^{-5}$, $d_2 = 1 \times 10^{-4}$, $d_3 = 1 \times 10^{-5}$ and $d_4 = 1 \times 10^{-4}$, respectively.

Fig. 4 EKF estimation results for Hodgkin-Huxley neuronal model.
For the HH neuronal model, EKF observer based state estimation results are obtained and presented in Figure 4, respectively. It is seen that the EKF is slower than the DBGO and SMO. The design parameters of the EKF are determined through grid search as follows: $P_0 = 10^{-4}I_4$, $Q = 0.1I_4$, and $R = 10^{-1}$, respectively.

**Table 2: Comparison results of designed observers**

<table>
<thead>
<tr>
<th>HH Model</th>
<th>DBGO</th>
<th>SMO</th>
<th>EKF</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>0.1723</td>
<td>0.3283</td>
<td>0.5293</td>
</tr>
</tbody>
</table>

The numerical simulations are summarized in Table 2 for the HH neuronal model. The RMSE errors of the estimations are similar with figures. It is seen that the DBGO observer is much better than both SMO and EKF for the model based neuronal model state estimations. DBGO observer is based on the mathematical model of the system such that there is no parameter to adjust. However, SMO and EKF are difficult to design. Neuronal model has fast dynamics and the states have small values. Therefore, it is one of the difficulties for parameter adjustment and the selection of sampling time in integration routine.

**V. CONCLUSIONS**

The designed nonlinear observers can be discussed and compared addressing the design conditions and performance results. The design conditions are mostly about the parameter selection and updating rule of the designed observer. If we want to order the designed nonlinear observers here about structural complexity, the simplest one is the SMO observer, which is designed as a classical sliding mode observer in this study. Beside its simple structure of classical SMO, there is faced very difficult parameter selection problem. For a four state system estimation, there is required to define eight parameters. Second observer is the DBGO observer here which has a complex state updating rule is based on the gradient update. The advantage of the DBGO is that there is no parameter tuning for a state estimation. On the other hand, there is needed to define Jacobian matrix and detailed update rule based on the RK discretization. Third observer is the EKF. EKF has a parametric structure where the estimation accuracy depends on the choice of process and measurement noise covariance matrices. Finally, we can rank the sensing algorithms from the one having the simplest structure to the most complex one as SMO, DBGO, EKF, respectively.

In order to compare the performance of the designed observers for state estimation results of HH neuronal model the Table 2 can be seen in detail. In the experiments, SMO exhibits better estimation performance than EKF. This is mainly because SMO exhibits robustness to the parameter uncertainties such that there could be uncertain or un-modeled dynamics of the systems. Moreover, DBGO does not need parameters which rectify the error dynamics where Levenberg-Marquardt direction is chosen for the faster convergence. There is an important difference between DBGO observer and other observer results in the Table 2. The second order gradient direction of the DBGO observer makes very fast the observer dynamics. However, it has a lack of robustness since any tiny change in the dynamics affect the observer performance.

As a general result, if we want to design a feedback controller or an online fault estimator, we need to check the model uncertainty and noise existence. If there is small unmodeled dynamics, the DGBO is a suitable selection. In the case of noise and uncertainty, the SMO must be chosen.

**REFERENCES**

Simplified minLLR Early Stopping Criterion for Belief-Propagation Based Polar Code Decoders

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Abstract—Polar code is one of the major breakthroughs in information theory field by its theoretically proven capacity achieving error correction property and low encoding, decoding complexities. Since Arikan submitted his original paper, researchers have made many improvements on both decoding and encoding sections. Successive cancellation (SC) and belief propagation (BP) is widely used decoding algorithms for polar codes. To reduce the complexity of BP decoder, early stopping methods are studied in literature. In this paper we simplify early stopping method for BP decoder by using channel polarization phenomena and we reduce the complexity of early stopping section by observing only a small cluster of information bits which are polarized to the highest error probabilities. Simulation results shows that early stopping detection algorithm needs to observe only n/8 bits instead of n for considered code length and rates without any performance loss and faulty early stopping detection.

Keywords—Polar code, belief propagation decoder, early stopping detection

I. INTRODUCTION

As the first theoretically proven capacity-achieving error correction code, polar code [1], draw serious attention by its low encoding and decoding complexities. After polar code is introduced researches are focused on developing more efficient encoding and decoding algorithms.

There are two main decoding algorithms for polar code, belief propagation (BP) and successive cancellation (SC) as a special form of BP [1], [2]. Both decoders have their own advantages and disadvantages. SC decoder has a serial structure which increases the latency with low decoding complexity [2], [3]. On the other hand BP has parallel structure which is suitable for parallel hardware implementation with high complexity [2]. Scaled min-sum (SMS) BP decoder proposed in [4] offers a great deal of complexity reduction over original BP decoder.

As all the other iterative decoding algorithms without early stopping detection SMS BP decoder needs fixed number of iterations for decoding [5]. With the help of early stopping methods some of the redundant iterations might be avoided. In [3], two early stopping methods, G-matrix and minLLR, for BP based polar code decoder are proposed. Another simplified early stopping method called worst of information bits (WIB) is proposed in [6]. Unlike G-matrix and minLLR methods, WIB method uses only a small cluster of information bits to detect successful decoding. In this paper we propose simplified minLLR method using this idea of WIB method.

II. SMS BP AND EARLY STOPPING CRITERIA

A. SMS BP Polar Code Decoder

BP is a commonly used algorithm for decoding of block codes [5]. SMS BP is basically the same algorithm with min-sum approach and a scaling factor. SMS BP has a similar performance with BP while having a significantly reduced complexity and a hardware friendly structure. For a (n,k) polar code there is (n = 2^m) m-stage factor graph representation. Factor graph representation of (8,4) polar code and single processing element (PE) showed in Fig. 1 and Fig. 2, respectively. Here, n is the code length and k is the amount of information bits and m is the number of factor graph layer and each layer of factor graph includes n/2 PE. Update equations for decoder are given in Eqn. (1-4). In Eqn. (1-4) log-likelihood ratio(LLR) values for right and left direction referred as R and L LLRs, i is bit index, j is layer index and t is iteration number.

![Fig. 1. Factor Graph Representation for an (8, 4) Polar Code Decoder](image-url)
There are three early stopping criteria used for polar codes, two of them are proposed in [3] and the other one proposed in [6]. First method is called G-Matrix proposed in [3] and has the lowest average iteration amount along with the highest computational complexity. Second method is called minLLR also proposed in [3] with the highest average iteration amount and mid-level complexity. Last method is called WIB [6] and the method has the lowest complexity with mid-level average iteration amount.

1) G-Matrix Early Stopping Criterion: G-Matrix method has a basic approach, after re-encoding the decoded data if the results are equal to input data than decoder assumes decoding is successful. It has three main steps decision of input bits, decision of output bits and encoding of output bits to compare with input bits. If the compare operation does not yield any differences then decoding is assumed successful. This method includes encoding process at each iteration therefore it has a complexity disadvantage.

2) minLLR Early Stopping Criterion: minLLR method has a simpler structure than G-Matrix. This method only check for last layers LLR values magnitude and compares them with a pre-determined constant ($\beta$). If the minimum LLR value is bigger than $\beta$ value then decoding is assumed successful. For high signal to noise ratio(SNR) values, $\beta$ needs to be switched to a higher constant. This method has lower complexity than G-Matrix but has the highest average iteration amounts.

3) WIB Early Stopping Criterion: Polarization phenomena is fundamental of polar code. When a block is encoded with polar code, some of the bits polarize to high error probabilities and others polarize to low error probabilities. These bits then classified as frozen bits which have a fixed value and information bits which carry the information respectively. Third method uses this phenomena. This method called WIB early stopping criterion proposed in [6] and the method uses only small cluster of information bits which are polarized to the highest error probabilities called WIB. As suggested in [6] for $n$ up to 2048 it is enough to use $n/8$ bits to detect successful decoding. Method checks for LLR values sign alterations of WIB. If there is no sign change of WIB LLR values during last $M$ iterations, decoding is assumed successful.

In this study we combine the idea of WIB method with the structure of minLLR method.

C. Proposed Early Stopping Criterion

As we know from [1], polarization occurs at different levels for different bit indexes. While some of the bits polarize well others could not polarize as needed. Semi-polarized bits used as information bits cover the great proportion of error probability according to rate of encoder. In [6] this idea used for simplifying entire early stopping detection. Here we use the idea to simplify minLLR method proposed in [3]. As illustrated with Fig. 3, method has the same structure with minLLR method in [3]. Only difference is amount and index of bits used to detect successful decoding.

According to [6] WIB covers the information bits with the highest error probabilities therefore it makes sense to look up minimum LLR value inside the WIB cluster instead of entire block. To test validity of the idea we provide Table I which gives us the probabilities of minimum LLR values being outside WIB cluster and the average difference from actual minLLR value when minimum LLR is outside the WIB.
For simulation study we use the same methodology as in [3], [6]. During simulations we consider binary-input additive white Gaussian noise (BI-AWGN) channel. We choose code length as 1024 and we provide simulation results for various code rates (1/3, 1/2, 2/3). Scaling parameter for SMS BP algorithm is $s = 0.9375$. In Fig. 4, we provide bit error rate (BER) curves for various code rate and WIB number versus signal to noise ratio (SNR) over 10000 trials.

As illustrated in Fig. 4 there is no performance loss with proposed method along with complexity reduction for early stopping section which is also compared with Table II. Fig. 4 also tells us that $n_{WIB} = n/16$ is not enough to cover the semi-polarized bits.

The most important contribution of an early stopping criterion to an iterative decoder is iteration reduction performance. Since proposed simplified minLLR method has the same iteration reduction performance with original minLLR method we have not provided these results cause these results clearly stated in [3], [6].
TABLE II

COMPUTATIONAL COMPLEXITIES OF EARLY STOPPING METHODS FOR SINGLE ITERATION

<table>
<thead>
<tr>
<th></th>
<th>G-Matrix</th>
<th>WIB</th>
<th>minLLR</th>
<th>Simplified minLLR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add</td>
<td>2n</td>
<td>M + 2n/8</td>
<td>n</td>
<td>n/8</td>
</tr>
<tr>
<td>Compare</td>
<td>3n</td>
<td>-</td>
<td>2n</td>
<td>n/4</td>
</tr>
<tr>
<td>XOR</td>
<td>nlogn</td>
<td>n/8</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

In this study we proposed a simplification to an existing early stopping criterion (minLLR) for BP based polar code decoders by using a theory from another early stopping method (WIB). Simulation results show that there is no performance loss with simplified minLLR method compared to original minLLR or fixed iteration amount. Although this method has the lowest computational complexity for early stopping section, overall performance would be better if it is used with G-Matrix method because of average iteration numbers.

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Distribution Network Reconfiguration for Loss Reduction and Voltage Profile Improvement using B-PSO

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Abstract— Low and medium voltage (LV and MV) distribution networks are operated in a radial configuration, but their topology, especially when highly loaded, is usually meshed in order to improve system reliability and quality of the supply. This makes it feasible to configure the network after an outage to restore the service to affected sites. In addition, by modifying the topology of the network, power loss and node voltage deviation can be minimize. However, this network modification is a non-linear, multi-objective, constrained and combinatorial optimization problem. In this paper, Binary Particle Swarm Optimization (B-PSO) technique is employed for optimal network reconfiguration of primary distribution network. The objective of the proposed method is to minimize the total active power loss and voltage deviation experienced in the network. It is carried out subject to a variety of technical constraints, with the search space being the set of networks branches. To ascertain the efficiency of the proposed method and its practicability on multi-scale distribution systems, standard IEEE 16-bus, 33-bus and 69-bus test distribution networks are used. The proposed algorithm is implemented in MATLAB and MATPOWER environments. The results obtained signify the effectiveness of the proposed technique.

Keywords— Binary Particle Swarm Optimization, Distribution Network Reconfiguration, Loss Reduction, Voltage Deviation.

I. INTRODUCTION

Distribution networks (DNs) carry electrical power right from transmission system to the consumption sites. Being the last stage of the power delivery, DN contributes at least 40% of the total power loss occurring in the entire system [1]. Most DNs are built as weakly meshed but operated radially, for effective coordination of their protection systems [2, 3, 4]. This is done with aid of switches within a feeder or across different feeders as shown in Fig. 1. They are either normally closed (NC) sectionalizing switches; S1-S6 existing within each feeder and normally open (NO) tie switches; S7 and S8 connecting sections of different feeders [5]. DN is vulnerable to number of outages due its radial nature, as a fault on a single line can result in blackout to many customers [6]. As a result, many efforts have been made to suppress these complications and improve the reliability and quality of the supply. Among the techniques proposed is distribution network reconfiguration (DNR).

A. Reconfiguration Techniques

DNR is the process of varying the topology of DN by changing the closed/open status of sectionalizing and tie switches to optimize system parameters while maintaining system constraints [7]. Among the objectives of DNR includes reducing system losses, service restoration and relieving primary feeders either due to overload or allow maintenance activities on that feeder. For instance, in Fig. 1, the first feeder can be relieved by opening S1 and closing S7.

In the same vain, the middle feeder carries the loads on the rest of the feeders if S1 and S2 are open while S7 and S8 are closed. In either case, the radial configuration of network is always maintained.

However, this network modification is a non-linear, multi-objective, highly constrained and combinatorial optimization problem [8]. The complexity of the problem arises from the fact that distribution network topology has to be radial and power flow constraints are nonlinear in nature.

The early studies on the network reconfiguration were directed to the planning stage [9, 10]. The sole objective these researches is to minimize the cost of construction, giving no concern on the quality of the supply. The first recognized work which attempts to solve the problem of distribution system reconfiguration for loss reduction was presented by Merlin and Back [11]. Henceforth, many algorithms have been developed to solve this problem. In the proposed method, all switches in
the DN were closed and then the switches are opened successively to eliminate the loops.

Recently, some researches have integrated both the DNR and DG placement problems to improve the effectiveness of the DN. Thuan Thanh Nguyen et al. applied adaptive cuckoo search for DNR for DG allocation [1]. The objective of this technique is minimizing power loss and improve voltage stability. Similarly, in [12], DNR is applied to distribution feeder to allow increasing the penetration of plug-in electric vehicles and minimizing network cost. Power loss and voltage deviation minimization using DNR is presented in [13].

In this paper, binary particle swarm optimization (B-PSO) is applied for optimal DNR to minimize the power loss and voltage deviation in primary DN. The outstanding performance of the proposed technique is its ability to solve DNR problem on single feeder or multi-feeder DNs.

B. Binary Particle Swarm

Due the non-linearity and combinatorial nature of the DNR optimization problem, various techniques were applied for its solution. It can either be a single or multiple objective problem [6]. Both classical and heuristic optimization methods were applied for DNR problems. Mixed-integer conic programming is formulated in [5] to minimize power loss. In a similar work presented in [14], selective PSO is employed. However, in these studies less concern was given to voltage deviation.

The particle swarm optimization (PSO) was first introduced by Kennedy and Eberhart in 1995 [15]. It was developed through simulation of many simplified work, it has been found to be robust in solving continuous nonlinear optimization problems, PSO is attractive because very few parameters are required for its applicability [16].

The algorithm used in this paper, B-PSO, has an advantage of handling both discrete and continuous parameters. It involves initializing the search space with swarm particles, \(x_i\) randomly. The search space in this problem is the set of all the sectionalizing and tie switches. At each iteration, the position of \(i\)th particle is updated by its previous position in the velocity vector, \(v_i\) according to (1)

\[ x_i = x_i^{t-1} + v_i^t; \quad i = 1, 2, ..., P \quad (1) \]

Where \(x_i = [x_{i,1}, x_{i,2}, ..., x_{i,N}]\) represents the position vector of the \(i\)th particle at the \(t\)th iteration, and \(v_i = [v_{i,1}, v_{i,2}, ..., v_{i,N}]\) signifies the velocity vector of the \(i\)th particle at the \(t\)th iteration, \(N\) being the number of variables of the function to be optimized and \(P\) is the number of particles in the swarm. The velocity vector is updated according to the following equation:

\[ v_i = \omega v_i^{t-1} + \varphi_1 r_1 (p_{best}^{t-1} - x_i^{t-1}) + \varphi_2 r_2 (g_{best}^{t-1} - x_i^{t-1}) \quad (2) \]

Where \(p_{best}^{t-1} = [p_{best_{1,1}}^{t-1}, p_{best_{1,2}}^{t-1}, ..., p_{best_{1,N}}^{t-1}]\) is the best solution achieved for the \(i\)th particle at the \((t-1)\)th iteration, and \(g_{best}^{t-1} = [g_{best_{1,1}}^{t-1}, g_{best_{1,2}}^{t-1}, ..., g_{best_{1,N}}^{t-1}]\) is the best position found for all particles in the swarm at the \((t-1)\)th iteration. \(\varphi_1\) and \(\varphi_2\) are positive real numbers, called learning factors or acceleration constants, which are used to weight the particle individual knowledge and the swarm social knowledge, respectively. \(rand_1\) and \(rand_2\) are real random numbers uniformly distributed between 0 and 1 that make stochastic changes in the \(i\)th particle trajectory. Finally, \(\omega\) is the inertia weight factor, which represents the weighting of a particle’s previous velocity [17].

II. PROBLEM FORMULATION

The problem to be solved involves determining the optimal DNR, taking into account different technical constraints. The objective of the proposed technique is to minimize power loss and voltage deviation as formulated in objective function (OF) below.

\[ \min F \]

Where

\[ F = f_1 + f_2 \quad (3) \]

The first part of the OF is the index of power loss obtained by normalizing the power loss with its initial value as shown in (4)

\[ f_1 = \frac{P_{loss_{recong.}}}{P_{loss_{initial}}} \quad (4) \]

Where \(P_{loss_{recong.}}\) is the power loss after reconfiguration and \(P_{loss_{initial}}\) is the power loss before reconfiguration calculated as;

\[ P_{loss_{initial}} = \sum_{i=1}^{nl} R_i \left( \frac{P_i^2 + Q_i^2}{V_i^2} \right) \quad f o r \ i = 1, 2, ..., nl \quad (5) \]

The second segment of the OF, \(f_2\) is the index of the total voltage deviation. It is similarly obtained by normalizing its reconfigured value, \(V_{dev_{recong.}}\) with its initial value, \(V_{dev_{initial}}\).

\[ f_2 = \frac{\Delta V_{recong.}^{total}}{\Delta V_{initial}^{total}} \quad (6) \]

The total inherent voltage deviation is computed as;

\[ \Delta V_{initial}^{total} = \sum_{j=1}^{NB} |V_j| \quad f o r \ j = 1, 2, ... NB \quad (7) \]

The DNR problem solved by considering the following constraints:-

1. Voltage limit

\[ V_{j_{min}} \leq V_j \leq V_{j_{max}}, \quad j = 1, 2, ..., NB \quad (8) \]

2. Maximum permissible line current carrying capacity

\[ I_l \leq I_{max}, \quad l = 1, 2, ..., nl \quad (9) \]

Where

\[ I_l^2 = A_{ij} |V_i|^2 + B_{ij} V_i V_j - 2 V_i V_j (C_{ij} \cos \beta_{ij} - D_{ij} \sin \beta_{ij}) \quad (10) \]
Radial network structure (RNS), this mean no loop are allow in the network

\[
A_{ij} = g_{ij}^2 + \left( b_{ij} + \frac{b_{shij}}{2} \right)^2
\]

\[
B_{ij} = g_{ij}^2 + b_{ij}^2
\]

\[
C_{ij} = g_{ij}^2 + b_{ij} \left( b_{ij} + \frac{b_{shij}}{2} \right)^2
\]

\[
D_{ij} = \frac{g_{ij}^2 b_{shij}}{2}
\]

(11) (12) (13) (14)

3. Radial network structure (RNS), this mean no loop

\[
\sum_{i=1}^{m} a_i = n
\]

Note that the switch status can be indexed using either the corresponding nodes between which the line is connected as in \( a_{ij} \) or using the line number as in \( a_l \) (implies that the line \( l \) is not connected). Equation (13) is not sufficient, there is need for an additional set of constrains including loop approach, which stipulate that each loop in the meshed configuration has to be open and path-based approach which is based on the identification of reasonable alternative linking each bus to the substation [5].

III. TEST SYSTEMS DESCRIPTION

To ascertain the effectiveness of the proposed method and its practicability on small and medium-scale distribution systems, three IEEE standard test distribution networks are used.

The first system is 16 bus, 3-feeder radial distribution system. The network has total loads of 28.125 MW and 13.53 MVAr on 12.65 kV substation voltage. The lines between each bus has a sectional switch for the buses connected to the same feeder and a tie switch for the buses connected to two different feeders as depicted in Fig 2. There are 3 tie switches and 14 such sectionalizing switches are used in this system [18].

![Fig. 2 IEEE 16 bus test system](image)

The second test system used in the study is 33-bus distribution feeder with a total active and reactive load demand of 3.72 MW and 2.30 MVAr respectively [6]. It has 37 branches, 32 sectionalizing switches and 5 tie switches as shown in Fig 3.

![Fig. 3 IEEE 33 bus test system](image)

A medium scale system having 69 buses, 73 branches and 5 tie switches, is used. The network has a total load demand of 3.80MW and 2.70MVAr. Its topology is shown in Fig. 4 [1].

![Fig. 4 IEEE 69 bus test system](image)

Due to the low R/X ratio of these test feeders considered, the commonly used Newton Raphson load flow program presents lot of convergence problem, hence backward-forward sweep method is used.

IV. RESULTS AND DISCUSSIONS

The performance of the proposed method is evaluated on the aforementioned test systems. The improvement observed in the individual objectives are expressed as the percentage of their respective inherent values.

- 16-bus test system

As mentioned earlier, this test system has 3 tie switches and 14 sectionalizing switches. The algorithm determined optimal configuration by varying open/close status of the switches to minimize the objective function while respecting the RNS and other constraints. The optimal solution is obtained by closing \( s_{14} \) and \( s_{15} \) and opening \( s_{7} \) and \( s_{8} \) while maintaining \( s_{16} \) open as shown in Fig 5.

![Fig. 5 IEEE 16 bus test system](image)
With this reconfigured network, the power loss is found to be reduced by 8.8903% of the total loss established to be 514.0293 kW. The voltage deviation reduced by 12.3364% of its inherent value of 0.2140 pu. Summary of the optimal reconfiguration results are shown in Table I.

### TABLE I

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before Reconfiguration</th>
<th>After Reconfiguration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tie switches</td>
<td>14, 15, 16</td>
<td>7, 8, 16</td>
</tr>
<tr>
<td>Power loss</td>
<td>514.0293 kW</td>
<td>468.3304 kW</td>
</tr>
<tr>
<td>Voltage dev.</td>
<td>0.2140 pu</td>
<td>0.1876 pu</td>
</tr>
<tr>
<td>Min. Voltage</td>
<td>0.96824 pu</td>
<td>0.9707 pu</td>
</tr>
</tbody>
</table>

Switches that changes status during the reconfiguration has significantly affect the voltages of the neighbouring buses. From Fig. 6, it can be vividly seen that voltages of bus 10, 11 and 14 have greatly improved due to changes in s7, s8 and s15 respectively.

![Fig. 6 16-bus test system voltage profile.](image)

- **33-bus test system**
  
  Unlike the previous case, 33-bus system has one substation, which makes its DNR a little easier. The optimal configuration is tabulated below.

### TABLE III

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before Reconfiguration</th>
<th>After Reconfiguration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tie switches</td>
<td>33, 34, 35, 36, 37</td>
<td>7, 11, 14, 28, 32</td>
</tr>
<tr>
<td>Power loss</td>
<td>208.4592 kW</td>
<td>141.6346 kW</td>
</tr>
<tr>
<td>Voltage dev.</td>
<td>1.6610 pu</td>
<td>1.0991 pu</td>
</tr>
<tr>
<td>Min. Voltage</td>
<td>0.9108 pu</td>
<td>0.9413 pu</td>
</tr>
</tbody>
</table>

The optimal solution is obtained by closing s33 - s37 and opening s7, s11, s14, s28 and s32 as shown in Fig. 7.

![Fig. 7 Optimized Configuration of 33 bus test system](image)

As result of this reconfiguration, the power loss is found to be reduced by 32.0564% of the total inherent losses before reconfiguration while the voltage deviation reduced by 33.8290% of the initial deviation established to be 1.6610 pu, much better than those obtained in [14].

![Fig. 8 33-bus test system voltage profile.](image)

Since voltage deviation is included in the OF, buses with higher deviation experienced significant improvement in their respectively profiles. In addition, neighbouring buses to the switches altered, like bus 12, 13, 13 and 15, have appreciable improvement as depicted in Fig. 8 above.

- **69-bus test system**
  
  In spite of the higher number of buses when compared with the previous cases, the algorithm is capable of locating the switches to be opened in order to minimize the OF while maintaining RNS and other constraints. Table III summarizes the optimal configuration.

![Fig. 5 Optimized Configuration of 16 bus test system](image)
The optimal reconfiguration is achieved by closing s71, s72 and s73 and opening s14, s58 and s61 while maintaining s69 and s70 open as shown in Fig 9.

As result of this reconfiguration, the power loss is found to be reduced by 56.1761% of the total inherent losses while the voltage deviation reduced by 64.6758%. This improvement is much better than that obtained in [19, 20].

It is worth-noting to inspect the deterioration of voltages at bus 41–46 as shown in Fig 10. This is caused as result of transferring some loads from middle feeder; loads at bus 15 – 27 and bus 62 – 65. Initially these loads were not on this feeder. For the same reason, voltages at bus 49 and 50 after reconfiguration is less than that before the configuration.

In this paper, the binary swarm optimization algorithm is applied to solve distribution network reconfiguration. The objective of the proposed technique is to minimize the active power loss and voltage deviation. It is carried out subject to some technical constraints in addition to maintaining the radial nature of the network. The decision variables are the open/close status of the sectionalizing and tie switches. IEEE multi-feeder 16-bus and single feeder 33-bus and 69-bus test distribution networks are used for testing the proposed technique. One distinguishing feature of the proposed method is its ability to handle system with single and multiple feeders.

From the simulation result, the technique is capable of reconfiguring the networks effectively and minimized the objectives. With the optimized reconfiguration, the RNS is maintained in all the cases, no mesh network is formed. Even though 69 bus system has higher number of buses, yet the result obtained is much better than the previous cases. While reconfiguring the networks, opening or closing some switches resulted in transferring some loads from one feeder to another, hence overloading it. This can be observed at bus 41–46 due to introduction of loads at bus 15 – 27 and bus 62 – 65 by opening s14 and closing s71. Distributed generation is needed at those overloaded feeders to support its load carrying capacity.

It is envisioned as future work to incorporate distributed generation to support the loaded feeders. Same technique will be used to determine their optimal siting and sizing.

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REFERENCES


A Design Optimization Study of the Outer Rotor PMSM with Genetic Algorithm and Differential Evolution Algorithm

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Abstract—Today, the use of permanent magnet synchronous motors has increased in industrial fields and these motors have many different structures. The outer rotor structure is remarkable in terms of ease of design and torque density. This study proposes to design optimization of the outer rotor with genetic algorithm and differential evolution algorithm. The geometric sizes were selected as design parameters and the motor efficiency is used as objective function. The obtained results by using of each algorithm are compared and the industrial conclusions were presented. As a result, the results are satisfactory and the study is useful for academic and industrial technical staff.

Keywords—design optimization, differential evolution algorithm, genetic algorithm, outer rotor, permanent magnet synchronous motor

I. INTRODUCTION

Electric motors consume a large portion of the electrical energy in the world. Therefore, academic and industrial works related to energy consumption and high efficiency motors are more important.

Nowadays permanent magnet synchronous motors (PMSMs) have been preferred because of their high efficiency and torque density. Motor structures affect these merits. Here the outer rotor permanent magnet synchronous motors are remarkable. Generally these motors have common advantages as other permanent magnet synchronous motors for example gearless [1]. In low-speed applications, the surface mounted PMSM with inner rotor is most popular but in high-speeds the outer rotor is more appropriate for the permanent magnets can be protected from centrifugal forces in outer rotors. Moreover their torque density is greater due to the wide diameter of the air gap and the production costs of the outer rotor are suitable.

The stochastic methods have been used for electrical machine design optimization. These methods can give effective results to the very complex problems like motor designs [2], [3]. Some of the most famous of these methods are the genetic algorithm and the differential evolution algorithm. These methods do not require the initial solution or population. The objectives of the design optimization of the PMSMs based on stochastic methods are reduce the torque harmonics or to increase the efficiency of the motor [4].

This study was conducted to optimize the design of the outer rotor PMSM for high efficiency. The genetic algorithm and the differential evolution algorithm were run to provide the optimal efficiency values. As input parameters the structural parameters of the motor were taken. The optimization and the analytical results were compared and eventually the results are sufficiently.

II. DESIGN OPTIMIZATION STAGES OF THE PMSM

A. The Winding Layout

In this study, the investigated PMSM are the surface mounted with outer rotor and the number of stator slots and pole numbers are 12/10 respectively. The concentrated/double layer winding layout is shown in Figure 1. The winding factor is a good value for performance and it is 0.933 [5], [6].

![Fig. 1 The winding layout](image)

B. The Design Parameters and the Objective Function

The design of the permanent magnet synchronous motors is nonlinear study and it has different design parameters. Some of them are variables, invariables and constants. Therefore, the effects of these parameters on the objective are different in terms of ease and accuracy of the design. The design optimization parameters are the rotor diameter for the inner rotor or stator diameter for outer rotor D_r, magnet thickness l_m, air gap length δ, slot wedge height h_w, stator tooth width b_s, stator slot height h_s, ratio of the slot opening over the slot width k_open. The two dimensional geometry of the motor is shown in Figure 2 [7].

![Fig. 2 Two dimensional geometries of the outer rotor PMSM](image)
The diameter, the stack length, and the pole angle are constraints. For each motor the outer diameter is 340mm, the stack length is 120mm, and the pole angle is 126°.

The supply, power, and speed values for the motor are 340V, 2400W, and 250rpm. The remanence flux density and the relative permeability of the permanent magnets are 1.2T and 1.03.

\[
P_{\text{out}} = T \times \omega_{\text{mech}} \quad (1)
\]
\[
P_{\text{Cu}} = 3I^2 \times R_{\text{Cu}} \quad (2)
\]
\[
P_{\text{Fe}} = P_{\text{h}} + P_{\text{e}} \quad (3)
\]
\[
\eta = \frac{P_{\text{out}}}{P_{\text{out}} + P_{\text{Cu}} + P_{\text{Fe}}} \times 100\% \quad (4)
\]

where, \(\omega_{\text{mech}}\) is mechanical angular velocity, \(P_{\text{out}}\) is output power, \(P_{\text{Cu}}\) is copper loss, \(P_{\text{h}}\) is hysteresis loss, \(P_{\text{e}}\) is eddy current loss, \(P_{\text{Fe}}\) is iron loss, and \(\eta\) is efficiency of the motor.

### III. THE OPTIMIZATION ALGORITHMS

#### A. The Genetic Algorithm

Genetic algorithms (GAs) do not produce only one solution for any optimization problem. The aim of the GAs is to find the optimal solution in the solution space. Populations in the genetic algorithm are composed of independent individuals and the individuals have genes reflects the solution of the problem [8].

Genetic algorithms do not guarantee to investigate the optimal result. The GAs may converge to a local solution but also they do not require the solution of the initial solution. Genetic algorithms have three operators; reproduction, crossover and mutation. The reproduction selects the individuals with higher fitness values to keep the struggle for life by using roulette wheel, tournament or any other selection criteria. Crossover operator exchanges randomly the genes of two individuals. Mutation operator changes the string’s bit from a “1” to a “0” or vice versa so the convergence of the algorithm to the local solutions is prevented.

#### B. The Differential Evolution Algorithm

Differential evolution algorithm (DEA) is one of the famous optimization algorithms. The algorithm is basically similar to genetic algorithm. Furthermore the main feature of the DEA is the use of differential operator. Differential action shall be taken to evaluate fitness values on the parents’ genes by the differential operator, thus the quality of the population is tried to be increased. DEA shows superior performance because of very small number of parameters to be set and the understandable actual code sequence [8].

### IV. THE DESIGN APPLICATION AND THE EVALUATION OF THE RESULTS

In this study some assumptions were made about the motor design such as neglect of the mechanical strength, thermal loadability. Obviously, industrial manufacturability of the PMSM was neglected in the design optimization results. The saturation on the stator teeth and stator and rotor yokes were taken only as constraints. The constraint values are 1.8T for the stator teeth and 1T for the stator and the rotor yokes. The geometric parameters were mentioned as input design optimization parameters.

The genetic algorithm has the crossover ratio is 0.85 and the mutation ratio is 0.01 and both algorithms have the population number is 50, the iteration number is 50. The termination criterion of the GA and the DEA is iteration number. The algorithms have binary codes and each gene has ten bits.

According to pre-analytical design and design optimization of the PMSM, the efficiency and losses results were given in Table 1. The investigated outer rotor motor has a good efficiency. It is possible to say that the differential evolution algorithm obtained the better results than the genetic algorithm. At the same time in low frequency ohmic losses are more effective than iron losses.

#### TABLE 1

<table>
<thead>
<tr>
<th></th>
<th>Ohmic Loss</th>
<th>Iron Losses</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical</td>
<td>79.4W</td>
<td>44.4W</td>
<td>95.09%</td>
</tr>
<tr>
<td>GA</td>
<td>57.8W</td>
<td>40.7W</td>
<td>96.06%</td>
</tr>
<tr>
<td>DEA</td>
<td>56.8W</td>
<td>37.6W</td>
<td>96.22%</td>
</tr>
</tbody>
</table>

![Fig. 3 The convergence graphics of the algorithms](image-url)
algorithm may be fallen in a local solution it is absolutely weakness. The graphics of the GA and the DEA were shown in Figure 4. The DEA is more sensitive and strong.

V. CONCLUSIONS

The design optimization of the outer rotor PMSM was investigated by the genetic algorithm and the differential evolution algorithm. The obtained results show that the differential evolution algorithm has better results than the genetic algorithm. The ohmic losses are more important in low frequency application. Eventually, the design optimization study of the outer rotor permanent magnet synchronous motor and the results are acceptable.

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Microprocessor Based Antenna Reconfiguration Controller For 5G Communication Systems

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Abstract— In order to cover wide spectrum with high antenna gain, the reconfiguration process may be proposed as an alternative solution instead of using several antennas which is not efficient considering the size restriction situation. In this study, a microprocessor based antenna reconfiguration controller circuit is designed and fabricated. Designed circuit can be used to reconfigure the antenna frequency, pattern or polarization for the possible 5G communication requirements. Proposed antenna reconfiguration controller has the ability of switching selected PIN diodes in order to cover the desired frequency bands.

Keywords— Antenna reconfiguration, 5G communication

I. INTRODUCTION

The necessity of high speed communication drives researches to figure out new designs and algorithms. These developments may be in hardware or software side. In order to meet the high speed communication requirements, these developments should move on together. For example, considering a mobile phone, suitable software is loaded into different type microprocessors which manage several functions in the phone. On the other hand, electromagnetic properties of the communication device are also important. One of them is the antenna which converts electrical signals into electromagnetic waves and vice versa. The antenna in a mobile phone or base station should send and receive electromagnetic waves in different bands of the electromagnetic spectrum. In order to meet the communication standards, different types of antennas have been designed so far. Some electronics devices have more than one antenna to cover different bands. Another option is to use reconfigurable antennas of which the resonant bands can be rearranged by the operator. Moreover, beside frequency reconfiguration, different properties of the antennas can be reconfigured such as antenna pattern or polarization [1,2]. Several reconfiguration methods are used in literature [3-5]. However, electronic and optical reconfigurations are very topical these days. In this study, a microprocessor based reconfiguration tool is designed fabricated and tested. The designed antenna reconfiguration controller (ARC) can be applied for controlling 64 electronic or optical switches on the antenna surface. For the sake of simplicity, a monopole antenna is used in the testbed. However, considering a cognitive radio process which may be a possible network in 5G, the instant channel state information (CSI) will be necessary in order to focus on the desired frequency band. In this situation, a sensing antenna should be inserted into the system so as to scan and figure out the suitable frequency bands [6]. All these process address the frequency reconfiguration. On the other hand, it should be noted that pattern or polarization reconfiguration may be needed for the future communication standards.

The paper is organized as follows. In Section 2, the fabricated Antenna Reconfiguration Controller (ARC) is given. Section 3 gives and discusses the results. Section 4 concludes the paper.

II. ANTENNA RECONFIGURATION CONTROLLER (ARC)

The fabricated microprocessor based ARC is given in Fig.1. Parallel cables are connected to the one port of the 8 bit microprocessor. LEDs are inserted for testing the signalization correctly. In order to test the ARC, a monopole antenna is designed with one high speed PIN diode as an electronic switch. The aim of this testbed is to use a monopole antenna for two different frequencies. The monopole size can be selected to obtain the desired frequency band. However the bandwidth of the antenna does not change is this method.

![Fig.1. Fabricated Antenna Reconfiguration Controller](image)
III. RESULTS

Designed ARC has been tested for different types of antennas. Here the monopole test results are given. ARC activates or deactivates the switches which are inserted on the antenna surface in the antenna fabrication process. A Microchip brand processor is used and the schematic of the electronic card is designed by using Eagle 6.2 Layout. In this study, only one switch is used for the sake of simplicity. However if the number of switches need to be increased, in this case, a look up table may be designed and inserted into the microprocessor by software. A power supply and LCD screen are also seen in the testbed which is given in Fig.2. The simulated and designed monopole antennas are given in Fig.3.

In Fig.4 and Fig.5, the fabricated antennas on the ground plane are given. Monopole antenna length is 100 mm and the printed surface is Rogers 4350 substrate (\(\varepsilon_r=3.48\)). Designed antenna has special inductors capacitors for electromagnetic isolation and resistors for the current limiting process. Another important device on the antenna surface is the PIN diode. In this study BAP63-02 is selected from NXP company. These electronic devices have to be selected carefully since their electromagnetic effects may change the resonance frequency [7].

According to the results, when the switch is turned on the resonance frequency of the antenna is measured as 900 MHz. Conversely when the switch is turned off, the antenna resonance frequency is measured as 582 MHz. It is clear that the frequency reconfiguration process of an antenna can be realized simply by a high speed PIN diode and cheap electronic components. Pattern and polarization reconfigurations may be experienced for the future antenna studies.
IV. CONCLUSION

An antenna reconfiguration controller (ARC) is designed, fabricated and tested. A monopole antenna which is controlled by the ARC has been fabricated and operated for two different frequencies using a PIN diode. This antenna reconfiguration controller is inevitable part of the cognitive radio which is suggested as possible 5G networks in literature. Using this fabricated ARC, reconfiguration process can be applied up to 64 switches. This number can be increased but considering the complexity it is not suggested.

REFERENCES


Neurosky EEG Biosensor Using in Education

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Abstract — Brain is composed by neurons using electricity to communicate to each other. There is a great amount electrical activity in the brain due to collection of numerous neurons sending signal. Neurons send brainwaves detected by sensitive equipment like electroencephalogram or electroencephalograph (EEG). Beta waves emanates from brains responsible for problem solving or decision making. Some equipment like neurosky biosensor intercepts these brain waves. In this study, neurosky biosensor is used in measuring the meditation level of students in the physics course. Developed program process the data of neurosky biosensor sent and make decision about meditation level of student in the course. Program says that “your meditation level is low to pass another subject or solve the exam”.

Key words – Brainwaves, neurosky biosensor, EEG, education, neurolearning.

I. INTRODUCTION

Our brain is made up of billions of neurons using electricity to communicate to each other. There is a great amount of electrical activity in the brain due to sending signals. This electricity can be detected by equipment such as electroencephalograph (EEG). Electrical activity in the brain composes brainwaves. Brainwaves are produced by synchronised electrical pulses from masses of neurons communicating with each other. Brainwaves are divided into bandwidths to describe their functions as indicated in Fig. 1, however are best thought of as a continuous spectrum of consciousness.

Brainwaves change regard to what we’re doing and feeling. In the case of that slower brainwaves are dominant; we can feel tired, slow, sluggish, or dreamy. On the contrary in the case of that higher frequencies are dominant, we feel hyper-alert. Brainwaves are classified into groups with respect to frequencies in Hertz, like gamma, beta, alpha, theta and delta.

Frequency of delta waves changes between 0.5 and 3 Hz. Delta waves slowest whereas loudest brainwaves. Delta waves generated in deepest meditation and dreamless sleep.

Frequency of theta waves changes between 3 and 8 Hz. Theta waves generated in deep meditation and sleep.

Frequency of alpha waves changes between 8 and 12 Hz. Alpha waves responsible for now and no quite meditation. Alpha waves generated in calmness and learning.

Frequency of beta waves changes between 12 and 38 Hz. These waves are dominant in waking state of consciousness and engaged with problem solving and decision making.

Frequency of gamma waves, fastest changes between 38 and 42 Hz [1, 2].

Neurosky EEG biosensor, which is a non-invasive, dry and low cost, can intercept the brainwaves, measures the attention and meditation level is illustrated in Fig. 2. [3].

Fig. 2 Neurosky Biosensor

Neurosky EEG biosensors can be used in education [4]. Meditation and attention rates shows difference in the case of
different room colour. By changing the room colour these meditation and attention rates can be increased [5]. In order to observe how the rates changes, a lot of game is developed [6]. Neurosky EEG biosensor can be used for identifying the emotion while playing game [7]. In this study, neurosky EEG biosensors are used in measuring the meditation level of students in the course. Developed program process the data of neurosky EEG biosensors sent and make decision about meditation level of student in the exam. Program says that “your meditation level is low to solve the exam or pass to another subject”.

II. EDUCATION WITH NEUROSKY BIOSENSOR

We have developed a program by means of using neurosky biosensor. Firstly, instructors and students have to be sign up this program as demonstrated in Fig.3.

![Fig. 3 Sign up](image)

Instructors sign in the program and load the course materials in the form of text, power point, image and video. Main menu of the developed program is illustrated in Fig.4.

![Fig. 4 Menu of program](image)

As it is seen in Fig.4, average attention and meditation rate while studying is recorded. Instructor can enter the program and upload the course materials. The students can enter the developed program; wear the neurosky biosensor while studying. Firstly, courses are offered as shown in Fig. 5.

![Fig. 5 Offering the courses](image)

Secondly, subjects of courses are entered as depicted in Fig. 6.

![Fig. 6 Subjects of offered course](image)

Thirdly, lesson names, required average attention and meditation rate for subjects are determined as illustrated in Fig. 7.

![Fig. 7 Lessons of subjects](image)

Fourthly, course materials are uploaded into developed program as demonstrated in Fig. 8 a-b for text and video upload respectively.

![Fig. 8 Course material upload](image)

Finally, after course materials are loaded, student can enter the system and study the subjects. During studying period, attention and meditation rates are recorded. When the students want to pass another lesson in the case of lower meditation and attention rate, the system gives the warning like “your attention and meditation level is lower than predetermined value for that reason you cannot pass another lesson”. Also instructor can see the statistical mean of the meditation and attention rate as shown in Fig. 9.
Students study while wearing the neurosky biosensor as shown in Fig. 10.

If the meditation and attention rate of the students are higher than predetermined rates, they can pass to another lesson. Otherwise they are not permitted to pass another lesson as illustrated in Fig. 11.

FIG. 9 Statistical mean of the recorded values

III. CONCLUSION

Brain emanates brainwaves in doing or feeling something. These brainwaves can be intercepted and processed by equipment like neurosky biosensor. In this study, neurosky biosensor used for measuring meditation and attention rates of student. We have developed a computer program. Via the program, we load the course materials into system. Students enter the system with their user name and password. Then study the first subject. If meditation and attention rates are high students pass to second subject. Otherwise, students have to study the subject again. Whenever these rates are high, students pass to second subject.

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Adaptive Fault Tolerant Control for a Liquid Tank Process

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Abstract—Level control of liquids in coupled tanks is a basic requirement in many industrial processes. Liquid levels in tanks must be controlled accurately regardless of environmental circumstances. Minor faults in sensors, actuators or other system components that take place in processes where liquid level control is required can result in catastrophic consequences. In this case, a fault tolerant control system is needed. The controller must be either passive (passive) or in reconfigurable (active) type in order to compensate for the effect of actuator faults and maintain system reliability and performance. In this study, a water tank level control system and possible valve actuator faults are modelled. By designing different controllers and using modelled failures a simulation is constructed. To test the reconfigurable type controller performance against faults/failures, a model reference adaptive control system is implemented and compared with PI-controlled system.

Keywords—Actuator faults, fault modelling, fault tolerant control, model reference adaptive control, liquid tank

I. INTRODUCTION

Main industries where liquid level and flow control are essential include petro-chemical industries, paper production plants, water treatment industries, food processing industries, pharmaceutical industries, nuclear power generation plants, and automatic water drainage systems. Due to increasing demands on system performance and product quality as well as economic benefits, modern technical processes have become more complicated. These complicated systems are vulnerable to faults in sensors and actuators. Minor faults in sensors, actuators or other system components that take place in processes in which fluid level control is a basic requirement can result in catastrophic consequences. Control system in this case must compensate for the effect of actuator faults and must maintain system reliability and performance.

Failures are difficult to accurately predict in time and can be abrupt, incipient and intermittent [1]. They are classified according to their location of occurrence in the system. The impact of a fault can be a small reduction in efficiency but could also lead to overall system failure and system instability. Therefore, in the design phase of compensators a good actuator failure model that covers all possible cases is crucial and in the application phase, more practical. Different types of actuator models are available in both deterministic and stochastic manners for linear or nonlinear systems. Most of related studies consider deterministic actuator fault models [2]. They use various approaches in deterministic manner [3-15] and generally consider a specific case that once the actuator fails; it will stay at the faulty mode during the rest running process. In other words, the number of actuator failures is finite. However, in practice, especially for safety-critical systems, the failed actuator may recover itself by a self-repairing control system and the actuator may fail more than once during the operation process, that is, the number of actuator failures is infinite. The actuator failures are practically stochastic in nature. For instance, a normally open electrical contact in electrical switches, relays or breakers is required to be open when it is in a de-energized or relaxed state. However, at some moment, the contact may undergo abrupt disturbances, which turns it to be closed, and it may recover to be open again, that is, the contact may jump between closed mode (failure) and open mode (failure-free) in a stochastic manner. Several studies design compensators with stochastic actuator failure [17-25]. In [17-19], actuator failure model output represented with a failure or faulty matrix. This diagonal matrix takes ‘1’ and ‘0’ values, which correspond to total failure and normal operation conditions. Also values between ‘1’ and ‘0’ are considered which represent loss of effectiveness. The diagonal matrix is stochastic with a known distribution. Generally Bernoulli distributed sequences and Gaussian distribution are used to model failure behaviours. In [20-25], the aforementioned abrupt changes are modeled as a Markovian process. Markovian process is a stochastic model that can be used to model a random system that changes states according to a transition rule that only depends on the current state. [26] shows that for given adequate historical data, the abrupt changes can be modeled as Markovian process. In the studies cited above, the stochastic functions related to Markovian variables are employed to denote the failure scaling factors for each actuator.

It is needed to design control methods capable of ensuring nominal performance considering the occurrence of failures. This control is referred to as fault tolerant control (FTC) which has become of significant importance in the last decades. There are lots of approaches in FTC area and individual research has been carried out extensively. However systematic concepts, design methods and even terminology are still not standardized [2, 3]. In FTC systems, the achievable system performance depends on the availability of redundancies in the control system as well as the design approaches used in synthesis of fault-tolerant controllers. Recently, FTC systems are classified into two categories, namely, active FTCs, and passive FTCs. These two approaches use different design methodologies for the same control objective. However, due to the distinctive design
approaches used, each method can result in some unique properties. A general requirement for both methods is the existence of system redundancies which can be analytical or applied on hardware and difference is how the redundancy is utilized.

In passive approach, a list of potential malfunctions is assumed to be known a priori as design basis faults, and all failure modes as well as the normal system operating conditions are considered at the design stage. An active FTC reacts to system component malfunctions (including actuators, system itself, and sensors) by reconfiguring the controller based on the real-time information from a Fault Detection Diagnosis (FDD) scheme. The term “active” represents corrective actions taken actively by the reconfiguration mechanism to adapt the control system in response to the detected system faults. Adaptive control methods are very suitable for active FTC. Due to their adaptation ability in the case of system parameter changes, these methods are in self-reconfigurable type. In other words, they do not require the reconfiguration mechanism and FDD components if component and actuator faults are considered.

In this study, firstly, a general model for actuator fault/failure is given. Then, a simple single input single output water level control system with valve actuator is chosen as testbed since it is widely used in process industry. The level control process is modeled and simulated in order to show the effect of actuator faults/failures on closed loop system performance. A conventional PI controller is chosen to track reference water level. Then, in random time and mode, various fault/failure scenarios are taken into account. Conventional PI controller cannot compensate the failure effects since it has not a reconfiguration structure. Therefore a controller with that property is needed. A model reference adaptive controller is designed in this case and fault accommodation property is compared with PI controller.

II. PROBLEM FORMULATION AND SYSTEM DESCRIPTIONS

A. Actuator Failure Model

Faults are not a reduction in efficiency only; they also include other cases such as stuck/frozen/hard-over failure of control valves in the case of process control. To represent the actuator faults in a more general formulation, the following mathematical model can be used [26]:

\[
\begin{align*}
\dot{u}_i(t) &= \sum_k u_k(t) + (I - \sum_k) f_i(t) \\
\Sigma_i &= \text{diag}\left[\sigma_{i1}^*, \sigma_{i2}^*, ..., \sigma_{in}^*\right]
\end{align*}
\]

where \(u_i(t)\) is faulty actuator output, \(f_i(t)\) contains the values at which the actuators are stuck or floating or hard-over. \(I\) is the identity matrix and \(\sigma_{i0}^* = 0\) represents a total fault (i.e. a complete failure) of the \(i\)-th actuator of the system so that the control action coming from this \(i\)-th actuator becomes equal to the \(i\)-th element of the uncontrollable offset function \(f_i(t)\) , i.e., \(u_i(t) = f_i(t)\). On the other hand, \(\sigma_{i1}^* = 1\) implies that \(i\)-th actuator operates normally ( \(u_i(t) = u(t)\) ). The quantities \(\sigma_{ij}^*\) can also take values in between 0 and 1, making it possible to represent partial actuator faults. For different types of fault conditions the above model can be specified in detail as:

\[
\begin{align*}
\sigma_i' &= \begin{cases} 
0 & t < t_f \\
1 & t \geq t_f
\end{cases} \quad \text{Fault free} \\
\sigma_i' &= \begin{cases} 
0 & t < t_f \\
1 & t \geq t_f
\end{cases} \quad \text{Partial fault} \\
\sigma_i' &= \begin{cases} 
0 & t < t_f \\
1 & t \geq t_f
\end{cases} \quad \text{Stuck fault} \\
\sigma_i' &= \begin{cases} 
0 & t < t_f \\
1 & t \geq t_f
\end{cases} \quad \text{Hard-over fault} \\
\sigma_i' &= \begin{cases} 
0 & t < t_f \\
1 & t \geq t_f
\end{cases} \quad \text{Floating fault}
\end{align*}
\]

Practically, considered faults in (2) occur randomly with unknown size and mode. Some probabilistic properties can be added to the model to represent randomly occurring phenomenon. In this case, the failure model can also represent the failures occurring intermittently.

Faults are further classified as additive and multiplicative with respect to the way they are modelled. Additive faults are suitable for representing component faults in the system while sensor and actuator faults are mostly multiplicative by nature. Possible actuator faults in multiplicative type can be represented by:

\[
\begin{align*}
\dot{x}(t) &= \sum_k x_k(t) \\
\dot{y}(t) &= \sum_k y_k(t)
\end{align*}
\]

Such multiplicative actuator faults do not directly affect the dynamics of the controlled system itself, however they can significantly affect the closed-loop system and may even affect the controllability of the system.

B. System Model

In water level control system given in Fig. 1, water is pumped into the tank at the top through an actuated valve and at the bottom of tank the water drains through a pipe. The objective is to control the water level in the tank with zero steady-state error.
According to Bernoulli equation, the rate of flow of water through the pipe is given by:
\[ q_s = a \sqrt{2gh} \]  (4)

where \( h \) is the level of the tank, \( a \) is the pipe cross-section area and \( g \) is the acceleration of gravity. Conservation of mass yields the equation:
\[ \frac{dh}{dt} = q_s - q_e = q_e - a \sqrt{2gh} \]  (5)

where \( A \) is the bottom area of the tank, \( q_e \) is the inflow rate through the valve.

If we linearize the system around an operating point and ignore the pressure of the tank outlet, the system can be assumed to be first order but by taking valve dynamics into account, system dynamics become second order. The first order system transfer function between inflow rate and water level is:
\[ H(s) = \frac{R}{Q(s)} = \frac{R}{ARs + 1} \]  (6)

where \( R = h/q_e \) is the resistance at the outlet and the valve dynamics can be given with a first order transfer function between controller output \( U(s) \) and system input \( M(s) \):
\[ G_e = M(s)/U(s) = \frac{K}{T_s + 1} \]  (7)

Here gain \( K \) represents steady-state relation between input and output and \( T_s \) is the time constant of valve actuator.

C. Fault Tolerant Control Design

In normal operation conditions, a PI controller is able to track reference while in actuator fault case; an adaptation mechanism is needed because of changing closed loop system parameters. Therefore MRAC is integrated into the system such that PI-controlled system model in normal operation is the reference model of MRAC. PI controller can be represented by the following transfer function:
\[ G_{PI} = \frac{U(s)}{E(s)} = K_p \left( 1 + \frac{1}{T_s} \right) \]  (8)

Reference model is chosen such that valve dynamics and system parameters are unknown. In this case, the closed loop transfer function that has one zero and three poles with unknown coefficients of known signs can be written as follows:
\[ G_{r1}(s) = \frac{Y(s)}{R(s)} = \frac{b_3 s + b_0}{s^3 + a_3 s^2 + a_2 s + a_1} \]  (9)

In order to meet MRAC objective with a control law that is free of differentiators and uses only measurable signals, plant and reference model must satisfy some requirements such as plant numerator polynomial is monic, plant degree is known, plant relative degree is known; reference model numerator and denominator are monic Hurwitz polynomials and relative degree is the same as that of plant. In other words, reference model must be chosen to be strictly positive definite (SPR) to obtain a stable controller. Following the certainty equivalence principle, the controller given below can be used [27]:
\[ u = \theta^T \alpha(s) \left( \frac{y_p + \theta^T y_p + c_i \Gamma}{\Lambda(s)} \right) \]  (10)

where \( \alpha(s) \) is an arbitrary monic Hurwitz polynomial of degree \( n \). The controller given in (10) has known parameters \( \theta' \) i.e., the controller is designed for a known plant transfer function therefore it is named as model reference controller (MRC). However, by using certainty equivalence, we can define an update law and use the same controller with unknown parameters. We can write the equation in compact form as follows:
\[ u = \theta^T \omega \]  (11)

Let us define the parameter error as:
\[ \tilde{\theta} = \theta(t) - \theta' \Rightarrow \theta(t) = \tilde{\theta} + \theta' \]  (12)

By using (12), (11) can be written as follows:
\[ u = \tilde{\theta}^T \omega + \theta'^T \omega \]  (13)

In order to choose an adaptation law, we have to first find out how the tracking error is related to the parameter error:
\[ e = G_n(s) p' (u - \theta'^T \omega) = G_n(s) (p \tilde{\theta}^T \omega) \]  (14)

where \( G_n(s) \) is reference model transfer function; \( p' \) is the ratio of the plant and reference model high frequency gain. Following Lyapunov function is used to prove system stability:
\[ V(\tilde{\theta}, e) = \frac{1}{2} \tilde{\theta}^T P_n e + \frac{1}{2} p' [\tilde{\theta}^T \Gamma^{-1} \tilde{\theta}] \]  (15)

Here \( P_n = P_n^T > 0 \) and \( \Gamma = \Gamma^T > 0 \). By using Kalman–Yakubovich lemma and Lyapunov function above, adaptive law is obtained as follows:
\[ \dot{\theta} = -\text{sgn} \left( \frac{k_e}{k_n} \right) \Gamma e \omega \]  (16)

In the design procedure of above controller, we assume that system has relative degree 1 which gives the opportunity to design reference model as SPR. The reference model we consider for the plant has relative degree 2. In this case reference model \( G_n(s) \) can no longer be SPR. We can solve this problem by using the fact that \((s + p_0)(s + p_0)^{-1}\) is identity for some \( p_0 > 0 \) and rewrite the error equation:
\[ e = G_u(s)(s + p_0)\phi^* (u_j - \theta^* \phi) \]  
(17)

with \( u_j = \frac{1}{s + p_0}u \), \( \phi = \frac{1}{s + p_0}\omega \), which implies that the control law in compact form is:

\[ u = \theta^* \omega + \theta^* \phi \]  
(18)

The reference model degree is \( n=3 \) hence choosing the degree of \( \Lambda(s) \) as \( n-1 = 2 \), fixing \( \Lambda(s) = s^3 + s + 1 \) and taking \( \alpha(s) = [s \ 1] \) for \( n = 3 \) designed controller takes the following form:

\[
\begin{align*}
\dot{u} &= \theta^*_1(t) \left[ \begin{array}{c} s \\ s^2 + s + 1 \\ s^2 + s + 1 \end{array} \right]^T u + \theta^*_2(t) \left[ \begin{array}{c} s \\ s^2 + s + 1 \\ s^2 + s + 1 \end{array} \right]^T y_r \\
&+ \theta^*_3(t)y_r + \theta^*_4(t) + \theta^*_5 \phi \\
\theta &= -\Gamma \phi \text{sgn} \left( \frac{k_p}{k_m} \right) \\
\phi &= \frac{1}{s + 1} \omega
\end{align*}
\]  
(19-21)

III. SIMULATIONS

In this part, firstly, water level control process is modelled and a PI controller is chosen to track reference water level. Using (5), a simulation model is constructed with the model parameters given in Table I.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of tank, ( h )</td>
<td>2 m</td>
</tr>
<tr>
<td>Bottom area, ( A )</td>
<td>1 m²</td>
</tr>
<tr>
<td>Out pipe cross-section, ( a )</td>
<td>0.1 m²</td>
</tr>
<tr>
<td>Initial level height ( h_i )</td>
<td>0.5 m</td>
</tr>
</tbody>
</table>

![Table I: Process Parameters](Image)

Appropriate PI parameters are chosen to achieve good time response characteristics such as 10\% maximum overshoot and 10s settling time. The parameters that meet the time domain specifications are \( K_p = 0.65 \) and \( T_i = 2.86s \). Fig. 2 shows the simulation diagram of the system with valve dynamics. System simulation time is 150s and sample time is selected to be 0.01s. A square wave reference input that changes between 0.7 and 1.7 is applied and the response of the system in normal mode can be seen in Fig. 3.

![Fig. 2: PI-controlled simulated system block structure](Image)

![Fig. 3: PI-controlled system output response in normal mode](Image)

PI controlled healthy system given in Fig. 2 is subjected to least squares system identification process by using reference input data \( u \) and output response data \( y_r \). Plant parameters in the simulation are assumed to be unknown in order to take possible parameter variations and uncertainty in real system into account. As a result of identification the following transfer function is obtained:

\[
G_{eu}(s) = \frac{Y(s)}{R(s)} = \frac{3.65s + 1.32}{s^3 + 6.70s^2 + 4.52s + 1.32}
\]  
(22)

Figure 4 shows model reference adaptive controller integrated system simulation model. Before starting the simulations, an actuator failure block is constructed for valve actuator so that in any time of simulation, random failure mode with unknown size can be applied to closed loop system. A wide range of fault/failure cases of valve are considered such as; hard-over, lock-in-place, stuck open, floating failure, leakage, loss of effectiveness. Fig. 5 shows the structure of failure block integrated water tank model. Faulty actuator block with various failure modes that is integrated into simulation can be seen in Fig. 6.

![Fig. 4: Model reference adaptive controlled system block structure](Image)
In MRAC system simulations, total simulation time is 140s, sample time is 0.01s and a square wave reference input that changes between 0.7-1.7 with a period of 90s is applied. Failure responses of both adaptive and non-adaptive controller are examined from different aspects. Various types of failures considered in Section II are simulated. In addition, fault occurrence types that may differ such as incipient, intermittent and abrupt changes are also considered. Following figures show the performance of PI-controlled system and MRAC system in the case of complete or partly failures.

Simulation results show that adaptive controller can compensate for any partial failure regardless of its occurrence type such as abrupt, intermittent and incipient. It has also a good transient response while PI-controlled system exhibits undesired high amplitude oscillations and bad transient behavior in the case of intermittent faults. Furthermore, in incipient loss of effectiveness fault mode given in Fig. 7, PI controller may dramatically damage a real process. In abrupt loss of effectiveness case given in Fig. 8, MRAC adapts itself to system changes while PI controller exhibits an undershoot. In Fig. 9, an intermittent valve leakage occurs with 20s duration and PI control has an oscillatory transient behavior. In abrupt valve leakage case which response is given in Fig. 10, PI controlled system output oscillates continuously while MRAC keeps tracking the reference input. In abrupt occurrence type lock-in-place and hard-over failure cases given in Fig. 11 and Fig. 13 respectively, both controller types cannot accommodate the failures since the system has loose controllability property and does not have actuator redundancy. As it can be seen from Fig. 12, after an intermittent lock-in-place failure of 5s, both systems has the ability to track the reference signal.
In this study, a brief literature search about actuator failure modeling is given. A simple water tank level control model, which is widely used in process industry, is selected as benchmark system. Possible valve actuator failures of tank process are considered and modeled. A fault tolerant MRAC controller is designed for the system and controller performance is tested and compared with conventional PI control via simulations. Simulation tests reveal good performance of designed MRAC over conventional control in terms of eliminating actuator failure effects in transient and at the steady state. As a future work, designed controller will be implemented on a real system. Furthermore, stochastic failure model will be integrated into the system at the design stage and also a robust adaptive controller will be designed to compensate for the failures.

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Abstract— Wireless Sensor Networks (WSN’s) have been finding to itself new applications continuously. Many of these applications need location information of nodes. The localization of nodes can be made by range based or range free localization methods conventionally. Angle-of-Arrival (AoA), Time-Difference-of-Arrival (TDoA), Received Signal Strength Indicator (RSSI), Time-of-Arrival (ToA) are well known range based methods. Therefore AoA, ToA and TDoA have some hardware and software difficulties for nodes which have limited processing and power sources. However RSSI based localization doesn’t cost high processing resources or complex hardware modifications. Most of the WSN nodes already have RSSI measurement capability. However RSSI measurements is vulnerable to noise and environmental effects. Therefore error of RSSI based localization can be over to an acceptable level.

Centroid, APIT, DV-Hop and Amorphous are some of the range free localization methods. Range free methods can only give location information approximately but they don’t need any extra hardware or high processing capability.

In this study WSN nodes are assumed randomly or regularly distributed on a certain area. Some of the nodes are beacon nodes. The beacon nodes are assumed as having higher power resources and GPS receivers. The locations of nodes are assumed as fixed. The beacon nodes send their location information sequentially. Localization of nodes are made through RSSI and location information of beacon nodes. The mean of RSSI is calculated to reduce effect of noise on it. A rough location estimation made by weighted centroid. A probabilistic based location estimation and flower pollination algorithm (FPA) are used separately to make final decision about the location. Rough estimates are used to limit search area of flower pollination algorithm in order to reduce convergence time.

Keywords— RSSI, FPA, WSN, optimization, probabilistic.

I. INTRODUCTION

Recently, WSN has become popular study in communication. The apps like health, business, military and habitat are the factors which made WSN has been so popular [1]. Nodes which are the elements of the WSN have advantages as operating with low-power, having small physical structure, low-cost and communication capability with adjacent nodes in limited range [2]. These are the other reasons why the WSN is so popular.

One of the main objective about WSN is acquiring location information of the sensor nodes. The localization simply means determining physical coordinates of the nodes which are unknown. Location information of the sensor nodes carry vital weight for many WSN apps. For instance; monitoring and surveillance of volcano activities, tsunami risk in oceans, melting regime of the poles, wild animals under risk of extinction, mobility of civilian and military vehicles and agricultural fields require that.

In WSN’s, there are two typical node types. Anchor node (also is called Beacon) is one of them. Anchor node knows location information of itself and can send data to the adjacent nodes. Other one is called non-anchor node which estimates physical coordinates of itself by various methods through location information of the anchor nodes that are in coverage area of it.

In literature, various localization methods have been classified conventionally into two categories named as range-based and range-free methods. Range-based methods require additional hardware. Naturally, additional hardware makes it costly.

Angle-of-Arrival (AoA), Time-Difference-of-Arrival (TDoA), Received Signal Strength Indicator (RSSI), Time-of-Arrival (ToA) are well known range based methods. AoA needs angle of received signal, time based methods; ToA needs exact synchronization between nodes, TDoA needs multiple receivers and synchronization between these receivers [3]. Therefore AoA, ToA and TDoA have some hardware and software difficulties for nodes which have limited processing and power sources.

Range-free methods generally use hop-counting and local techniques [4]. As a feature Range-free methods don’t require additional hardware but location estimations are rougher than range-based methods. Centroid, APIT, DV-Hop and Amorphous are some of the range-free localization methods [5]-[6]-[7].

If RSSI based localization is taken into account, it is seen that it doesn’t require high processing resources or complex hardware modifications. Even it can be considered the least complex among the range-based methods. Most of the WSN nodes already have RSSI measurement capability. But on the other hand RSSI measurements are under effects of noise and environment. Therefore error of RSSI based localization should be over to an acceptable level. For the RSSI based localization noise and environmental effects are considerable problems. To reduce these effects, there are many methods have been proposed in literature. Some studies are based on
reducing of distance error by estimating of path loss parameters dynamically [8]-[9]. In another study, error is reduced by making a mapping database between RSSI and distance information [10]. On the other hand, particle filter usage may has been another solution for RSSI error. For instance, in reference [11] a new particle filter with a hardware-free initialization phase is presented. In other particle filter approach, multiple antenna arrays and particle filter are used together for reducing of RSSI error [12].

In this study, locations of nodes are assumed as fixed. Namely, environment is assumed as static. Therefore, path loss attenuation is also assumed a fixed value. In simulation scenario, the beacon nodes send their location information sequentially. Location estimations of the nodes are made through RSSI and location information of beacon nodes. The mean of RSSI measurements are calculated to reduce effect of noise on it. A rough location estimation made by weighted centroid. In the next phase, a probabilistic based location estimation and flower pollination algorithm (FPA) are used separately to make final decision about the location. Rough estimates are used to limit search area of flower pollination algorithm in order to reduce convergence time.

II. RECEIVED SIGNAL STRENGTH

RSSI method is based on location estimations of the non-anchor nodes by using signal strength of the anchor nodes where are in coverage area of the non-anchor nodes. Received Signal Strength (RSSI) can be formulated simply shown as (1).

\[
\text{RSSI}(dB) = P_{TX}(dB) - P_{LOSS}(dB)
\]  

(1)

Where, RSSI(dB) is received signal strength acquired at non-anchor node, \( P_{TX}(dB) \) is transmitter power of the anchor node, \( P_{LOSS}(dB) \) is path loss in the channel. Well-known models for path loss are Free Space, Log-normal and Hata [13]. Generally, environment where is WSN modules installed shows distortion effects like diffraction, multipath, obstacles etc. The most convenient path loss model for this kind of environments is Log-normal distance model [14]. In this model, path loss can be calculated through the equation shown as (2).

\[
P_{LOSS}(d) = P_{LOSS}(d_0) + 10 \delta \log\left(\frac{d}{d_0}\right) + X_0
\]  

(2)

Where, \( P_{LOSS}(d) \) is path loss value in dB that occurred at distance \( d \), \( X_0 \) is Gaussian noise with zero mean and standard deviation can vary between 4~10. \( \delta \) is path loss attenuation factor which can vary between 2~5. \( P_{LOSS}(d_0) \) is path loss value in dB that occurs at 1m distance. \( P_{LOSS}(d_0) \) is given 40.3dB in CC2538 catalogue [15]. Therefore we accepted \( P_{LOSS}(d_0) = 40.3\text{dB} \).

In simulations, a fixed path loss attenuation factor (\( \delta \)) is used because of anchor and non-anchor nodes are assumed to be fixed locations. In this conditions, path loss is under effect of Gaussian noise as seen in equation (2).

A. The Improvement of RSS Quality

First phase of proposed system is about improvement of RSS quality. Absolute uncalibrated RSSI/CCA accuracy is ±4dB in CC2538 catalogue [15]. This accuracy means ±8m location error at 25m distance under certain conditions. For some apps that accuracy is acceptable but not always. To reduce noise and improve the accuracy, anchor nodes should send signal sequences to its non-anchor nodes. Each non-anchor node gets RSS sequences from the anchor nodes that are at coverage area of it. Due to nodes are static, distances don’t change. In that case, mean of each RSS sequence is an improved RSS information because of Gaussian noise reduced. This is expressed mathematically in equation (3).

\[
\text{RSS}^{\text{IMP}} = \frac{\sum_{i=1}^{k} \text{RSS}_i}{k}
\]  

(3)

Where, \( \text{RSS}^{\text{IMP}} \) is improved RSS value that is acquired from anchor node, \( k \) is the number of sequence, RSS, is the \( i \)th RSS value that is acquired from anchor node. Improved RSS information is important for the distance information. For the next phase of the proposed system, distance can be calculated shown as equation (4).

\[
d_i = \frac{(P_{TX} - \text{RSS}^{\text{IMP}} - P_{LOSS}(d_0))}{10 \delta}  
\]  

(4)

Where, \( d_i \) is \( i \)th improved distance information of the anchor node which is in coverage area of the adjacent non anchor node.

Improved distance information is one of the important parameter for the applied pre-localization. In this study, we preferred weighted centroid algorithm (because of its simplicity).

III. WEIGHTED CENTROID

Weighted centroid is a RSS based localization algorithm [16]. Weights specify level of proximity of the anchor nodes according to the non-anchor node. Weights can be calculated shown as (5).

\[
w_i = \frac{\sum_{j=1}^{N} d_j}{N d_i}
\]  

(5)

Where, \( w_i \) is the weight of \( i \)th anchor node and \( N \) is the anchor node number in the coverage area. After calculation of the weights, rough coordinates can be calculated shown as equation (6).
\[ \bar{x}_r = \frac{\sum_{i=1}^{N} w_i x_i}{\sum_{i=1}^{N} w_i}, \quad \bar{y}_r = \frac{\sum_{i=1}^{N} w_i y_i}{\sum_{i=1}^{N} w_i} \]  

(6)

Where, \( x_i \) is abscissa of the \( i \)th anchor node, \( y_i \) is ordinate of the \( i \)th anchor node, \( x_r \) is abscissa of the estimated rough coordinates and \( y_r \) is ordinate of the estimated rough coordinates. Even if, the coordinates that are estimated through weighted centroid might be sufficient for many WSN apps, sometimes it might not be sufficient. Hence at the last step, probabilistic and FPA methods are used for the improvement.

### IV. PROBABILISTIC APPROACH

In this approach non-anchor nodes estimate their own location through probability density function (pdf). We can express the probability of non-anchor node location in limited area at two dimensional space as in (7).

\[
P_{k}(x_r,y_r) = \int_{x_{r_{min}}}^{x_{r_{max}}} \int_{y_{r_{min}}}^{y_{r_{max}}} f(x,y) \, dx \, dy
\]

(7)

Where, \( P_k(x_n,y_n) \) is the probability of the non-anchor node, \( x \) can change between \( x_{min} \) and \( x_{max} \) and \( y \) can change between \( y_{min} \) and \( y_{max} \) which are bounding coordinates. \( \Delta x \) and \( \Delta y \) are arbitrary small values [17].

The first phase of this approach is calibration phase. RSS measurements are collected at different distances between anchor and non-anchor node. The mean value of RSS measurements \( \mu_{RSS}(d) \) and standard deviation \( \sigma_{RSS}(d) \) can be calculated from measurements, where \( d \) defines distance. In reference [17] it is mentioned that in theory and experiments \( \sigma_{RSS} \) doesn’t vary significantly with the distance. If \( X_0 \) is 0, RSS probability of any distance \( d' \) is equal to 1.

\[
p \rightarrow P_k \left( d' = 10^{0.05 (P_{RSS} - P_{LOSS}(d_0))} \right) = 1
\]

(8)

Practically, channel is under effect of shadowing. Thereby, distribution of distance for a fixed RSS value is log-normal. Consequently in calibration phase, log-normal mappings of the RSS measurements are acquired [17].

Second phase of the probabilistic approach is localization with positive constraints. In this phase, each non-anchor node estimates its pdf position through the log-normal mappings of the RSS measurements.

At first, each non-anchor sets initial estimation for entire network area. Then, anchor nodes send information which includes their own position information and updated pdf estimations of both their own and non-anchors to the adjacent nodes. Non-anchor receives the information and executes the following algorithm;

- RSS measurement is done from received packets,
- RSS is mapped to the one dimensional pdf acquired from the first phase, and a pdf constraint is generated which is function of the 2D coordinate.
- Old pdf is intersected with generated constraint and update is done.
- At last, non-anchor node sends updated pdf estimation to all its adjacent nodes.

Consequently, final estimations for the non-anchor node coordinates are made according to the maximum probability evaluation.

### V. FLOWER POLLINATION ALGORITHM (FPA)

Pollination process in the nature consists of two different forms called biotic and abiotic forms. Biotic pollination is carried out by pollinator creatures as bird, bat and bee. 90% of all pollination events take place in biotic form. And remaining 10% happens in abiotic form that is occurred by wind or water diffusion. It does not include any pollinators. Pollinators travel to long distances to reach plants that they wish. They maximize the pollination probability of the same-species via flying over other species. Pollination process happens in two main types as self-pollination and cross-pollination. Self and cross-pollination are shown in Fig. 1.

- Cross-pollination is defined as pollination that occurs among different plants in the same species. Thus, pollinators are very effective for the cross-pollination. On the other hand, if the pollination occurs in the same plant, this is defined as self-pollination. While self-pollination might occur in different flowers of the same plant, it might also occur in same flower of the same plant [18].
- Pollinators like bird, bat and bee show Lévy Flight behaviour and flying steps show Lévy distribution [19].
- Pseudo algorithm of the FPA can be expressed as below.

**Rule (1):** Biotic and cross-pollination is accepted as global pollination process. Pollinators who carry pollens show Lévy Flight behaviour.

**Rule (2):** Abiotic and self-pollination is accepted as local pollination process.

**Rule (3):** Flower pollination constancy is proportional with the probability of breeding between two similar species.

Fig. 1 Pollination types
Rule (4): Global and local pollination probability is controlled by a switching probability which is defined as $p \in [0, 1]$. The effects like physical proximity, wind and local pollination are considerable part of the global pollination. As a result, they are also considerable for the switching probability. In other words, these effects can be changed by controlling switching probability.

In global pollination phase, the most convenient pollination can be achieved by pollinators who can travel to long distances. While the most convenient pollination parameter is $g_b$, flower pollination constancy can be expressed mathematically as in (9).

$$\phi_i^{t+1} = \phi_i^t + L(\phi_i^t - g_b) \tag{9}$$

Where, $\phi_i^t$ is the $i$th solution vector in $t$th iteration, $g_b$ is the best solution in $t$th iteration and $L$ is the step size which is characterized by Lévy Flight [18-19].

Flower constancy for local pollination can be expressed mathematically as in (10).

$$\phi_i^{t+1} = \phi_i^t + \epsilon(\phi_j^t - \phi_k^t) \tag{10}$$

Where $\phi_j^t$ and $\phi_k^t$ defines pollens where they come from different flowers of the same plant species. If $\phi_j^t$ or $\phi_k^t$ comes from the same species or selected from the same population, it shows random walk characteristics with uniform distribution as defined $\epsilon [0, 1]$ [18]. Consequently, flow chart of FPA can be drawn as shown in Fig. 2.

In this study unlike the conventional FPA algorithm, rough solutions and improved data are integrated to the algorithm. Objective function of this optimization phase is expressed in equation (11).

$$J(x, y) = \sum_{i=1}^{k} \frac{d_i - \sqrt{(x_i - x)^2 + (y_i - y)^2}}{d_i} \tag{11}$$

Where, $J$ is the cost or objective function, $k$ is the anchor node number in communication range of the non-anchor node, $d_i$ is the improved distance information between $i$th anchor node according to the non-anchor node, $x_i$ is the abscissa of the $i$th anchor node, $y_i$ is the ordinate of the $i$th anchor node, $x$ is the abscissa of the pollen and $y$ is the ordinate of the pollen. In the objective function, $d_i$ is subtracted from the distance between pollen and adjacent anchor node of itself. Then, absolute value of the result is divided to $d_i$ to avoid cumulative optimization error. Consequently, global best is acquired by minimizing the value of sum of dependent errors of the every pollen.

VI. SIMULATIONS AND RESULTS

In simulations, anchor nodes are located edge of the 30x30m square area in equal intervals. Transmitter power of the anchor nodes are assumed to 1mW. Non-anchor nodes are assumed at fixed location and deployed randomly in defined area.

For the channel, path loss attenuation is assumed as fixed ($\delta=2.7$) and previously determined through experimentally. Gaussian noise is assumed as zero mean and standard deviation is 5.

Also, iteration and particle number are selected 20, switching probability is selected 85% for the FPA.

In the light of these assumptions, results are acquired by changing two parameters. The first parameter is physically intervals of anchor nodes. The second parameter is about number of RSS samples that acquired from the anchor nodes.
Number of RSS samples were selected fixed value as 10 and number of the non-anchor nodes were selected as 20 for the first analysis. Intervals of the anchor nodes were changed respectively 10-15-30m. Under these conditions, simulation results which contain mean-errors are shown below separately and respectively.

In second analysis, number of RSS samples are increased to 50. Simulation results for each distance interval are shown below.

Mean errors for each methods are shown in Table I. As can be seen, for each distance interval, FPA localization gives the best results.
increasing the RSS samples to 50 improved the location accuracy approximately 50% for the FPA.

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>RESULTS FOR RSS SAMPLE=50</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Error</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Weighted Centroid</td>
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<tr>
<td>Probabilistic</td>
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</tr>
<tr>
<td>FPA</td>
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</tr>
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</table>

VII. CONCLUSIONS

In this study, two different approaches are analysed which used weighted centroid rough results. Both the methods showed improvement according to the weighted centroid localization. When comparison is made between two methods, it shows us that FPA has more accurate results and lower processing load. As a future work, RSSI based location accuracy improvement for mobile nodes will be examined.

REFERENCES


"Flower pollination algorithm for global optimization"
Development of Cascade H- Bridge Multi-level Inverter for photovoltaic Panels.

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Abstract— in this paper a cascade inverter based on photovoltaic system is proposed and the control method which is used in this inverter is the charge balance control method in order to equalize the amount of power which drawn from each h bridge(except the first one ). As a result the batteries life of the inverter which is consider the most important component of the inverter will increase .Also the magnitude of the dc sources is selected in such a way that the number of levels which are produced is more than symmetrical cascade inverter .All of the expressed theoretical results are confirmed by simulation and experimental results.

Keywords— cascade multilevel inverter, photovoltaic, full wave charge balance control method, buck – boost dc to dc converter, perturb and observe maximum power point method.

I. INTRODUCTION

Today, cascade H bridge multilevel inverters have got more interest according to their essential advantages such as: high voltage and high power ratings applications, excellent power quality, lower order harmonics, reduction in switching losses [1-2] .The output waveform of these inverters is synthesized from several dc voltage sources as inputs.

Generally the multilevel inverters are divided into three types according to the topology structure, diode clamped multilevel inverter, flying capacitor multilevel inverter, cascade H bridge multilevel inverter [3].There is more focus on cascade H bridge multilevel inverter because of its simple design ,simple maintenance, the ability of generating large number of output levels by using the same number of the semiconductor devices as compared with the other topologies [2-3].Depending on the above advantages, the losses and the cost will be reduced, on the other hand the efficiency will be improved [2] .The sub classifications of cascade multilevel inverter are the symmetrical and asymmetrical inverters if one of the input dc sources is different and then we can recognize that inverter as asymmetrical inverter[2-5] which can produce more numbers of output levels and amplitude than symmetrical type[6] .The most distinct feature of cascade multilevel inverter is that it need separate dc sources as an input so it is considered the most suitable way to use with renewable energy sources such as pv panels which increases interest because of the Global increasing demand , reduces the negative impact of the power generations on the environment, needs no fuel cost and reduces the transmission losses in case of off grid which serves the regions far from transmission lines and generation units [4] .

Several methods are used to control the cascade h bridge multilevel inverter .Some of these control methods are : [6]:

- Fundamental frequency control method
- Sinusoidal pulse with modulation method
- Space vector pulse with modulation method

The Fundamental frequency control method is considered the most applicable method. In this method every semiconductor device is turned on one time per fundamental cycle and that leads to reduce the conduction losses and the electromagnetic interference [6]. On the other hand it has the drawback related to the amount of power which drawn from one DC source which is different from the other sources, so the battery life will be different from each other and that leads to high maintenance cost [2] .In order to overcome the disadvantage of this method the charge balance control method is proposed in this work to equalize the amount of power drawn from each Dc source.

In this paper, firstly we introduce the basics of cascade H bridge multilevel inverter, secondly brief description of the pv system and then the simulation and practical results will submit the proposed cascade inverter.

II. CASCADE MULTI-LEVEL INVERTERS

Generally, the key component of cascaded inverter is the full bridge unit which is shown in Fig. 1.[11].it is used to produce three level output waveform (vdc, 0and -vdc) with different duty cycle. It consists of four switches which can conduct in bidirectional power flow and can block unidirectional voltage. This reason is behind the connecting of anti-parallel diode with the switching devices and in case of pure resistive loads we can use the semiconductor switch without the anti-parallel diode due to unique current direction .Each switching device has to switch on in a complementary manner with another switch in the same arm to avoid the short circuit across the source so all the control
strategies are built according to this fact, e.g. when s1 is on s3 is already off and when s2 is on s4 is already off.

These H bridges are connected to distinct DC sources in the supply side while the diode clamped and flying capacitor requires common DC source and connected in series in the output side. We can call it as ac side Fig.2. It Show the single phase diagram of cascaded H bridge inverter[11] according to cascaded inverter configuration, the control and modulation and maintenance are modular.

![Fig.1. Full H bridge (three level output)](image1)

![Fig.2. Single phase diagram of cascaded inverter](image2)

Where \( v_o \) represent the output voltage of the cascaded inverter and it can be calculated by adding the amounts of \( v_1(t), v_2(t), \ldots, v_N(t) \). Where N is the number of the cascaded bridges.

The relationship between the produced number of output voltage levels (n) with respect to the number of connected cells N in symmetric converters is:

\[
n = 1 + 2N
\]  
(1)

and the maximum output voltage \( v_o \) is given as a function with the DC sources that cascaded as:

\[
v_{\text{max}} = N \cdot v_{\text{dc}}
\]  
(2)

From the above two relations, we can recognize the most related disadvantage of this topology which is increased of the DC sources and the semiconductor switches when we aim to increase the output levels, so to reduce the number of DC sources and also the semiconductor switches and the connecting cables the asymmetrical cascade h bridges multilevel inverter is proposed. This produces maximum numbers of levels and by utilizing the same number of the DC sources and H bridges, in [9] and [10] the manner of selecting the DC source voltages is binary progressing in [9] and ternary progressing in [10] and the output levels (n) is given as (3) and (4).

\[
n = 2^{N+1} - 1 \quad \text{in binary progress ratio}
\]  
(3)

\[
n = 3^N \quad \text{in ternary progress ratio}
\]  
(4)

By comparing the equations (3)-(4) by (1) it is clear that the output levels increase in the asymmetrical topological at the same time by keeping the same number of switching device and DC sources. This is just an example to show the difference between symmetric and asymmetric inverter topologies. The dependent way for determining the values of DC sources in this paper is also based on asymmetrical configurations and selected to be as follows [12].

\[
v_{\text{dc}1} = v_{\text{dc}}
\]  
(5)

\[
v_{\text{dc}, m} = 3^m v_{\text{dc}1} \quad m = 2, 3, N
\]  
(6)

And the output levels number is given as:

\[
n = 6N - 3
\]  
(7)

Where N is the number of the series connected H bridges. The reason behind the selection of this manner is according to the fact that we cannot use the charge balance control method in [9] and [10], because of different voltages of the batteries.

The main advantages of this method as compared with the fundamental frequency control method is to equalize the amount of power which drawn from different batteries. As a result, battery life will be equal which will reduce the maintenance cost. Several modulation patterns can be used to implement the charge balance control method, in fullwave pattern the angles will route continuously after one cycle while in halfwave pattern the routating angle will routeate after half cycle. If any pattern is used we will make all the DC sources get charges and be balanced after a specific time of operation expect the battery which is used in the first h bridges so the amount of power will be given as:

\[
P_{\text{DC}, k} = \frac{1}{T} \int_0^T v_{o_k} \cdot idc_k \, dt
\]  
(8)

Where \( T \) is the time duration to equalize the power drawn from the bridges.

In Fig.3, a seven level symmetric cascade inverter is implemented by fundamental frequency control method, full

In this paper we will use the fullwave control pattern. It mean the conducting angle will rotate after every full cycle.

III - Interview of photovoltaic system.
Generally, solar cells generate electric potential from sun energy by photovoltaic module which is built from silicon cells. And always the output of these cells has been low so a photovoltaic array is formed to increase the total potential output. The array can be formed by a series or a parallel connected of solar cells to increase the produced voltage or current of the module, pv cells gives its maximum output power in one specific point. This point is called the maximum power point and it depends on the loads, temperature and irradiance. According to this characteristic the pv cells or the photovoltaic module cannot operate in its maximum power point without an external effects which forced the pv panel to operate in its maximum point so that one of the maximum power point tracing algorithm have to be used with the dc-dc converter to maintain the operating point of the panel near the maximum power point area[4]. Some of these techniques are Constant Voltage MPPT Algorithm, Perturb and Observe (P&O)MPPT Algorithm, Incremental Conductance (INC) MPPT Algorithm[8], and the other important component is the dc-dc converter such as : buck, boost, buck boost converter to be merged with the mppt algorithm to ensure that the module will operate in it is maximum power point tracing and to construct the solar charge controller [7], in this paper we will use the following components:

A- buck-boost dc-dc converter

B- perturb and observe mppt algorithm.

A- BUCK -BOOST DC-DC CONVERTER

Generally, DC-DC converter is an electronic circuitry that is capable of producing different levels of dc voltage, many conversion processes are used in these converters such as switch mode, linear, and magnetic[7].

Some of the most famous topologies is buck, boost, buck-boost converters, in buck converter the output voltage is less than its input while in boost converter the output voltage is greater than the input voltage. In buck boost type as it is clear from the title of this converter it is able to work as buck mode and boost mode. As mentioned above, we will use this type of converters together with mppt algorithm so our big attention will be around the buck-boost converter, two operation mode can be used in this converter, the continuous conduction mode (ccm) if the current of the converter never reaches the zero region while the other operating mode is called the discontinuous operating mode (dcm) when the converter current reaches the zero region during the time period the equation of all calculation is different from one mode to another.

In this paper we will use the continuous conduction mode (ccm) the output voltage is calculated as:

$$v_o = vi \frac{b}{1-b}$$ (9)

While in discontinuous conduction mode (dcm) the output voltage is calculated as:

$$v_o = vi \frac{b^2}{2Io}$$ (10)
Where \( D \) is the duty ratio which will feed the controlling switch and \( V_o \) in both modes in average values.

\( I_o \) is the current through the load.

In continuous conduction mode (ccm) when \( D < 0.5 \) it will operate in buck mode while when \( D > 0.5 \) it will be in boost mode.

In Fig. 4, it shows the diagram of the buck boost converter [7]

![Buck-boost DC-DC converter diagram](image)

Fig. 4. Buck-boost DC-DC converter

The basic idea of operating is that when the switch is closed then the inductance \((L)\) will charge while when the switch is open the inductance polarity is reversed and the current path will be through the diode \((D)\) and capacitor \((C)\).

In this paper buck-boost dc-dc converter is used and there are several reasons behind the selection of this model of buck-boost converter in this work some of them are:

- ability of operating buck mode and boost mode
- easy to design
- reduce the cost
- reduce power losses
- less component required

One feature of this type of converters is the output of this converter has the opposite polarity with respect to its input.

B. perturb and observe maximum power point tracking algorithm (p&o mppt)

Pv cells are considered the most adverts source of renewable energy because of its availability and the positive impact of this energy in the environment, on the other hand some of disadvantage of this kind of renewable energy its direct effect in the weather condition, temperature, irradiance, etc... So in order to solve this problem and ensure that the pv module operate in its maximum point or nearby of this point, many techniques can be used to do this mission such as Constant Voltage MPPT Algorithm, Perturb and Observe (P&O) MPPT Algorithm, Incremental Conductance (INC) MPPT Algorithm. In this work we will use perturb and observe method according to its simplicity and accuracy. In the Fig. 5, bellow it shows the flow chart of this technique [8].

In this method, the sign of the last perturbation and the sign of the last increment in the power are used to decide what the next perturbation should be. On the left of the MPP, incrementing the voltage increases the power whereas on the right decrementing the voltage increases the power.

![Flow chart for Perturb and Observe Algorithm](image)

Fig. 5. Flow chart for Perturb and Observe Algorithm.

One of the disadvantages of this method is the operating point which will be around the maximum point, not the exact maximum point and one process to increase the accuracy of this method is by decreasing the step time (\( dt \)) but the module will take very long time to operate in its maximum point.

IV-simulation results

Simulation results in matlab 2015A are used to prove the operation of the charge balance control method the pv module which is used to charge the batteries continuously and its type is bpx150. The pv panel generate its maximum power at \( V_{mp} = 34.5 \text{v} \) and \( I_{mp} = 4.35 \text{A} \). So due to control method, e.g, 14 volt is the voltage of first H bridge. The results the dc to dc converter will operate in buck mode \( d < 0.5 \) because the pv module operate at its maximum power point in \( V_{mp} = 34.5 \text{v} \) while the voltage of the second and third H bridges are equal to \((3\times V_{dc1})\) which is equal to \( 42 \text{v} \) so the dc to dc converter will operate in boost \( d > 0.5 \).
Figures (6-7-8) below show the duty cycles of the first, second and third bridges respectively.

From the above figures it is clear that the first pv module operates in buck mode and its duty cycle around 0.36 (less than 0.5) according to the buck-boost dc-dc converter characteristic while the second and the third H bridges operate in boost mode and its duty cycle = 0.56 (greater than 0.5).

The battery voltage of the first, second and the third is as follows: vdc1 = 12.5 - 14 v

Vdc, 2, 3 = 41.5 - 42 v

We put this range according to the control which is merged with the mppt algorithm to control the battery voltages.

The voltage of the batteries is shown in the figures (13-14-15):

Figures (16-17-18) show the output of each H bridge and the final waveform (15 levels) is shown in fig 19 which represents the summation of the three H Bridges voltages.
An anti-parallel diode is connected to each semiconductor switch to allow bidirectional current flow and block unidirectional voltage. The diode type used is (In4007). The voltage which is used in the first H bridges is 6 v while the second and the third are 18 volts the output of the three H bridges is shown in figures (21-22-23)

**V-EXPERIMENTAL RESULTS**

The laboratory setup consists of a single phase 15 level cascaded asymmetrical multilevel inverter. This inverter consists of three H bridges which is able to produce 15 level output with a maximum output voltage equal to 7 vdc.

Each H bridge consists of six semiconductor switch. Four of them build the H bridge frame and the type of this transistor of the prototype are tip142 (nnp bjt) for the upper Q1,Q3 and tip147(pnp bjt) Q2,Q4 for the lower while the other two transistors are used for controlling and the type of them are 2n3904(npp) Q5,Q6. Fig . 20 shows one H bridge diagram in hardware configuration.
VI-Conclusions
In this work an improvement in the cascade inverter is done. This improvement includes two points: the first is related to the number of the output levels which is increased by using the asymmetrical topology with minimum number of dc sources and semiconductor switches and the second concern with the amount of power which is drawn from each DC source (except the first source) is equalized by using the charge balance control method. This inverter works perfectly with direct connected batteries and pv panels as shown in the simulation result, also experimental work shows the performance of the proposed inverter.

The output wave form of the inverter (15 level, 7 positive, 7 negative, 1 zero) is shown in Fig.24.
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SVDD Based Data-Driven Fault Detection

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Abstract— Conventional data driven process monitoring algorithms are limited to Gaussian process data for principal component analysis (PCA) algorithm and non-Gaussian process data for independent component analysis (ICA) algorithm. This paper provides a comparison study between the conventional data driven methods and support vector data description (SVDD) algorithm for fault detection (FD). Different from the traditional methods, SVDD algorithm has no Gaussian assumption. Thus the distribution of process data is not important for SVDD method. In order to compare their FD performances of the proposed methods from the application viewpoint, Tennessee Eastman (TE) benchmark process is utilized to compare the results of all the discussed methods. Simulation results on TE process show that ICA and SVDD methods perform better for false faults than the PCA method.

Keywords— Process Monitoring, Fault Detection, Support Vector Data Description, Independent Component Analysis, Principal Component Analysis, Statistical Process Control

I. INTRODUCTION

In statistical process control (SPC) systems there exist many variables need to be monitored. These measurements provide useful information about the status of the systems. So applying the univariate SPC methods on that systems may produce false alarms. Using multivariate SPC (MSPC) methods can overcome that problem. MSPC has several advantages over univariates, for example, showing relationships between variables which cannot be detected with univariate statistics, and help to understand the interaction between variables. PCA and ICA algorithms have been widely used as a multivariate statistic intended to find latent variables in the FD field [1-6].

PCA is a well-known algorithm, and depends only on the second order statistics which means that the latent variables capture the most variance of the source signals. Unlike PCA, the goal of ICA algorithms is to minimize the statistical dependence between the basis vectors, and there is no closed form expression for ICA algorithms.

Another efficient FD algorithm is SVDD algorithm proposed by Tax and Duin [7]. SVDD algorithm aims at finding spherically shaped boundary around a data set. In this boundary, a hypersphere enclosing most of the data set belonging to the class of interest and rejecting the outliers. SVDD is a new method in the FD area, but it has been used in a wide range of FD applications [8-10]. In this paper, it is employed the one-class SVDD to find the separating boundary the normal data set and faulty data set. In this respect, SVDD is implemented and compared with standard MSPC methods for FD.

The remainder of this paper is organized as follows. Section II describes PCA and ICA algorithms. How to obtain SVDD algorithm is given in section III. Section IV gives monitoring results of the application to TE process. Finally, section V provides a concluding summary of this paper.

II. PROCESS MONITORING BASED ON PCA AND ICA

The basic model considered in PCA and ICA is

\[ x = As \]  

(1)

where \( s = [s_1, ..., s_d]^T \) is a vector of unknown source signals which are independent, and \( x \) is observation vector which is mixtures of the source signals via unknown mixing matrix \( A \). The objective of PCA is to make variables uncorrelated through orthogonal rotation. The orthogonal rotation matrix is obtained by using eigenvalue decomposition on covariance matrix

\[ \Sigma = \frac{XX^T}{m-1} = VAV^T \]  

(2)

where \( \Lambda \) is the diagonal eigenvalue matrix with its diagonal elements in decreasing order, \( V \) is orthogonal eigenvector matrix. The loading matrix \( P \) is formed by a first vector which possesses acceptable percent of data variance. The transformation of \( X \) matrix is called as the score matrix and calculated as follows

\[ T = XP \]  

(3)

The transformation into the original space is achieved by using

\[ \hat{X} = TP^T \]  

(4)

The residual matrix \( E \) is calculated as

\[ E = X - \hat{X} = X - TP^T \]  

(5)

PCA algorithm divides data space into two parts. First part is determined by a first major component and has the greatest data variance. The other part is defined by a small percentage of data variance and shows noise. \( T^2 \) statistic can be used to measure the variation of PCA model for a loading vector.

\[ T^2 = x^TVA^{-1}_aV^Tx \]  

(6)

where \( A_a \) is the first \( a \) rows and columns of \( A \). In PCA the \( X \) data is assumed to follow a multivariate normal distribution so \( T^2 \) follows an \( F \) distribution with degrees of freedom \( A \) and \( A - M \), and confidence limits can be calculated as follows

\[ T_{a}^2 = \frac{A(M^2 - 1)}{M(M - A)} f_{A,M-A,a} \]  

(7)
Squared Prediction Error (SPE) statistic measures the average size of the residuals corresponding to the lowest \(d - a\) eigenvalues

\[
SPE = x^T(I - PP^T)x
\]  

(8)

The confidence limit of SPE statistic is defined as

\[
SPE_\alpha = \theta_1 \left( \frac{h_\alpha c_\alpha \sqrt{2\theta_2}}{\theta_1} + 1 + \frac{\theta_2 h_\alpha (h_\alpha - 1)}{\theta_1^2} \right)^{\frac{1}{2}}
\]  

(9)

where \(c_\alpha\) is the value of normal distribution with \(\alpha\) level of significance.

ICA tries to estimate source signals without knowing \(A\) and \(s\). In order to achieve that, Hyvarinen introduced a fast-fixed point algorithm (FastICA) [11]. In FastICA, Negentropy method is used to measure statistical independency. The negentropy is defined as \(J(y) = H(y_{gauss}) - H(y)\), which can be approximated by

\[
J(y) = \left[ E[G(y)] - E[G(y_{gauss})] \right]^2
\]  

(12)

where \(G(y)\) is the nonquadric function [12]. The FastICA algorithm is stated as follows

1. Choose an initial weight vector \(w\) of unit norm.
2. Update \(w \leftarrow E[zg(w^Tz)] - E[g(w^Tz)]w\), where \(g(y) = tanh(a,y)\)
3. Normalize \(w \leftarrow w/\|w\|\)
4. If not converged, go back to step 2.

Separating matrix \(W\) is obtained by assembling all the vector \(w\), and the demixing sources are calculated as

\[
\hat{s} = Wx
\]  

(13)

After obtaining \(W\), it is divided into two parts, dominant part \((W_d)\), excluded part \((W_e)\), and using these parts three statistics are calculated as follows

\[
l^2 = S_d^2 \hat{S}_d = x^T W_d^T W_d x
\]  

(14)

\[
l_e^2 = S_e^2 \hat{S}_e = x^T W_e^T W_e x
\]  

(15)

\[
SPE = (x - \hat{x})^T (x - \hat{x})
\]  

(16)

where \(\hat{x} = (\Lambda^{-\frac{1}{2}} P^T)^{-1} B_d W_d x\). In ICA, the latent variables are assumed to be non-Gaussian distributed, hence the confidence limits of tree statistics are calculated by kernel density estimation method [13].

III. PROCESS MONITORING BASED ON SVDD

The SVDD is a new method in the FD that constructs a univariate monitoring statistics for variables [14]. The aim of SVDD is to transform original variables into a high dimensional feature space by using kernel. The transformed variables fall into a minimal sphere of radius \(R\) [7]:

\[
\min_{\hat{s},a,c} R^2 + C \sum_{i=1}^{n} \varepsilon_i s.t. \|\phi(\hat{s}_i) - a\|^2 \leq R^2 + \varepsilon_i
\]  

(17)

\[
\varepsilon_i \geq 0 \quad \forall 1 \leq i \leq n
\]

where \(a\) is the center of hypersphere, \(C\) is the trade off between the volume of the hypersphere and the number of transformed samples outside the hypersphere, and \(\varepsilon_i\) is slack variable. The \(a\) and \(R\) are obtained as follows

\[
a = \sum_{i=1}^{n} \alpha_i \phi(\hat{s}_i),
\]

(18)

\[
R = \sqrt{K(\hat{s}_p,\hat{s}_p) - 2 \sum_{i=1}^{n} \alpha_i K(\hat{s}_p,\hat{s}_i) + \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i \alpha_j K(\hat{s}_i,\hat{s}_j)}
\]

(19)

where the sample points \(\hat{s}_p\) is support vector. Using (17), the univariate monitoring statistic is calculated as

\[
d^2(\phi(\hat{s}_i)) = \|\phi(\hat{s}_i) - a\|^2
\]  

(20)

If the square distance \(d^2(\phi(\hat{s}_i)) = \|\phi(\hat{s}_i) - a\|^2 \leq R^2\), sample is accepted as a normal sample. The decision based on SVDD can be precisely described as

\[
d^2(\phi(\hat{s}_i)) = K(\hat{s},\hat{s}) - 2 \sum_{i=1}^{n} \alpha_i K(\hat{s},\hat{s}_i) + \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_i \alpha_j K(\hat{s}_i,\hat{s}_j) \leq R^2
\]  

(21)

IV. COMPARISION STUDY BASEN ON TE

In this section PCA, ICA and SVDD methods will be applied to TE process for a comparison study. TE simulator was developed by Downs and Vogel which produces two products from four reactants [15]. It has five major units, i.e. reactor, condenser, compressor, separator, and stripper. There are 41 measured variables and 12 manipulated variables. In TE process, 20 process faults and an additional valve faults were defined by Downs and Vogel [15]. The sample length of the training data set is 500 under normal operating conditions. Each testing data set for one fault mode consist of 960 samples, and fault was introduced at sample 160 for each data set. All the data were autoscaled prior to application of the algorithms. To obtain better effect of simulation, 52 variables are selected for analysis. The confidence limit of kernel density estimation is selected as 99%. Fault detection rate (FDR) and false alarm rate (FAR) are considered to evaluate FD performance [16,17]. FDR and FAR rates are defined as

\[
FDR = \text{No. of samples} \ (f > J_{th} | f \neq 0)
\]  

(22)

\[
FAR = \text{No. of samples} \ (f > J_{th} | f = 0)
\]  

(23)
If one of the test statistics exceeds threshold, a fault can be detected successfully. The FD performances of the methods are investigated for 11 typical fault modes in TE process, and the results are calculated and tabulated in Table I. Also, in Table I the fault types and fault modes can be seen. As it can be seen in Table I, FDRs are almost the same, and are lower than PCA. Therefore, ICA and SVDD algorithms can be preferred to PCA to obtain lower FARS, and may provide the process operator with more reliable information. The drawback of the ICA algorithm is that using the kernel density estimation method is computationally expensive. Unlike the ICA, SVDD does not suffer from a high computational load, so using SVDD is more appropriate for FD applications.

V. CONCLUSIONS

In this paper, PCA, ICA and SVDD methods have been introduced, which was based on linear (PCA, ICA) and nonlinear process monitoring techniques (SVDD). Then, all the methods were implemented on TE process to compare the sensivity of the algorithms quantified by calculating the FARS.

According to Table I, all the tested methods give similar FDRs but different FARS (Table II). However FARS of ICA and SVDD have almost the same, and are lower than PCA. Therefore, ICA and SVDD algorithms can be preferred to PCA to obtain lower FARS, and may provide the process operator with more reliable information. The drawback of the ICA algorithm is that using the kernel density estimation method is computationally expensive. Unlike the ICA, SVDD does not suffer from a high computational load, so using SVDD is more appropriate for FD applications.

REFERENCES


Line of Sight (LoS) Probability Prediction for Satellite and HAPs Communication in Trabzon, Turkey

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Abstract— The knowledge of Line of Sight (LoS) probability is crucial to estimate signal attenuation correctly in mobile wireless communication. Especially in built-up areas, more accurate LoS probability determination helps to obtain more realistic propagation models or path loss models. Geographic Information Systems (GIS) and City Information Systems (CIS) are used to provide a necessary data to calculate the LoS probability. In this study, LoS analyses are made via Arcgis software for the most well-known streets in Trabzon, Turkey. For these analyses, the Earth’s surface is accepted as flat and a simple geometrical approach is used for calculations in this paper. A Matlab algorithm was created to calculate LoS probability depending on the elevation angle which is an important parameter for satellite services. LoS probability vs. elevation angle is presented for interested streets. As a result, LoS probability for Trabzon dependent elevation angle is estimated and presented.

Keywords— Line of Sight, Line of Sight Probability, LoS, Wireless Communication, GIS, CIS, Arcgis, Arcmap, Elevation angle, Matlab

I. INTRODUCTION

The increasing demand for higher data rate in wireless mobile communications services has expedited the need for more innovative and flexible communications infrastructures. Terrestrial ground-based systems and satellite systems are used for providing mobile communications services [1]. To overcome some of the disadvantages of both terrestrial ground-based systems and satellite systems, high altitude platform stations (HAPS) technology can be used to provide cellular communication. So, there is plenty of research in this area [2]. In [1], researchers obtain propagation models and performance analyses for HAPS systems. It is obvious that elevation angle is the dominant parameter on the propagation models in [1]. The simplest definition of Line of Sight (LOS) is the straight path between two fixed points in two or three dimensional space when unobstructed by the horizon. On the other hand, non-line of sight (NLOS) is indirect path from one point to the other points in two or three dimensional space. LOS is an ideal condition for mobile ground communication because transmitted signal is received with best possible signal strength without exposing any obstacles [1]. In NLOS, there are many obstacles such as buildings, trees, forest, poles, tunnels and traffic lights. In this case, transmitted signal reaches the receiver weakened. Apart from these, transmitted signal also get attenuated due to rain. In urban type environment, the signal gets attenuated especially by buildings. Urban type environment is covered dense buildings which are closely located to each other and streets. Therefore, transmitted signal gets attenuated as a result of diffraction and reflection caused by these buildings.

In urban type environment, when examined it was observed that signal quality in mobile communication systems is significantly affected on the streets for LOS and NLOS cases [1]. Therefore, the height of the buildings, transmitter height, receiver height, elevation angle from receiver to transmitter, street widths and lengths are most important factors to determine the LOS and NLOS conditions created by buildings. In terrestrial mobile communications, above mentioned characteristics of the building and the street can be obtained via digital maps which is used in geographic information systems (GIS) [3]. Transferring the entire city to digital map is a difficult and sensitive process. This has led to the emergence of City Information Systems (CIS) [4]. In Turkey, all municipalities are gradually creating their City Information Systems (CIS). Some of these cities are İstanbul, İzmir, Eskişehir, Konya, Kayseri, and Trabzon. In this study, City Information Systems of Trabzon Municipality is used to obtain LOS probability values [5].

A lot of software is available in the GIS and many of them are paid. ARCGIS [6] and MAPINFO [7] could be given as an example for most commonly used paid software. Also, NETCAD [8] can be given as an example national paid software. Some of the most commonly used free software is GRASS [9], QGIS [10] ve SAGA GIS [11]. Urban Information System of Trabzon Municipality was created by the NETCAD
software. In this study, GIS data sets received from Trabzon Municipality is adapted to ArcGIS software.

In her study [1], Hasırcı used direct sight (LOS) and non-direct sight (NLOS) probability values from Holis and Pechac [12]. Depending on this probability values, propagation models have created and performance analyses of communication channels are made in [1].

In this study, the most well-known streets and avenues for the city of Trabzon were considered. For each street and avenue LOS and NLOS probabilities were calculated depending on the elevation angle through a code written in Matlab. After that, calculated LOS probabilities for streets were combined with Bayes conditional probability theorem [24] by performing simulation to create Trabzon city LOS possibilities.

Realistic LOS probability values calculated in this study will be put in LOS probability equation (1) from [12] and HAPs propagation models and performance analyses will be obtained for Trabzon. Also, these calculated real probability values can be used to estimate propagation and coverage area for Trabzon.

This LOS modelling idea is not new. Actually, LOS analyses were used in the military fields. First LOS analyses were made at the beginning of the 18 century by the French military engineer Prestre de Vauban (1603-1707). LOS analyses slowly began to gain importance over the following years because of increasing military activities as a result of wars [13]. LOS analysis has played an important role in military especially for the placement of an optimum observation tower, selection of military areas, and preparation of war plans.

ArcGIS software one of most commonly used GIS software. ArcGIS™ technology, developed by ESRI, is a scalable integrated Geographic Information System (GIS) software. ArcObjects is a development environment of the ArcGIS family of applications [14]. In this study, ARCMAP which is one of the module of ArcGIS software is used. ARCMAP has provided visualisation of available graphical and verbal data, data update, query and analysis, charting and reporting tools and, it also has high quality cartographic production functions. In ArcGIS 3D analysis tool, there are functions such as LOS (places visible and not visible among a line), Viewshed (visible areal places and not visible areal places for desired specific point of view) and drawing LOS profile [14].

Height of buildings and the distances between the buildings are important parameters for radio propagation models and LOS probability calculations [1]. In the literature, it was shown that building height distributions have similarities with some known probability distributions.

When these studies were analyzed, it is clear that rayleigh distribution is most commonly used distribution. Log-normal distribution is also used in some studies. Some references state that building height densities are similar to log-normal distribution rather than Rayleigh distribution while creating radio propagation models [16,17]. The distributions related to the height of the building are also investigated thoroughly in [15], [17] and [18].

Cheng and Wu have represented the LOS calculation model which determines security and route for vehicles traveling at highway [19]. Led and Pechac, using the ITU-R P.1410 model, use the data from existing GIS to calculate the LOS coverage probability in Prague capital city of the Czech Republic [20]. Oestges and Janvier have represented the physical and statistical model of LOS coverage probability calculation for HAPs [21]. Saunders and Evans has provided a physical model which calculates the probability LOS for land mobile satellite systems derived from a simple geometric model [22]. RamaSarma, in his research, has calculated the probabilities of LOS for interested regions and stated it analytically [23]. RamaSarma is used two models in his research namely CRABS and PLEXTEK which estimate visibility [23]. Both models have a structure that will be an alternative to the ray tracing method in the literature. In both models, required parameters are produce by statistical methods from existing GIS data. Using these parameters, the radio propagation models were estimated.

II. LINE-OF-SIGHT PROBABILITY MODELLING APPROACH

In this section, propagation modelling and statistical study for channel performance analysis on HAPs systems in [1] were investigated. In above mentioned study, the analytical LOS probability expression depending on elevation angle was obtained. In her research, Hasırcı emphasizes propagation modelling of HAPs and gives performance analysis [1]. All possible propagation environments were divided into four groups: suburban (SU), urban (U), dense urban (DU) and urban high rise (UHR) area. These propagation environments were modeled using well-known statistical models with a dependence on elevation angle. Focusing only urban areas in this study provides a more detailed examination. With rapidly growing metropolitan areas, more detailed studies that have become much more important in signal attenuation will help to solve this problem. Statistical models were combined with free space path loss, and full formulations of total path loss for the four possible HAPs propagation environments and different conditions at 2-6 GHz frequency band were obtained [1].

Elevation angle and propagation environment are the most important parameters to determine propagation characteristics for HAPs systems.

First, using ITU-R Rec. P.1410 [17] statistical model, LOS and NLOS probability distributions corresponding to each elevation angle in each propagation environment were calculated [12], the data has been created to be used in the produced model.

Probability distribution for LOS and NLOS corresponding to each elevation angle have been created on the following geometry for four propagation environment [see Fig. 1]. This geometry is essential scenario for simulation result in this paper.
A 2 x 2 km size city area was considered in analyses and the layout of the building sampled every meter in simulation setup. Simulation were separated in two group. In first group simulations, LOS probability in the streets was analyzed as a function of elevation angle for different propagation environment filled with buildings. A much simpler geometry was shown in Fig.1 for LOS and NLOS conditions of area. Calculations were made every 9 degree increments for azimuth angles in a range of from 0 to 360 degrees. Initially, buildings were randomly generated by the statistical models. After that, to implement and analyze a large number of scenarios, HAPs location were determined separately for each sampled point of the street for given elevation and azimuth angles. LOS probability for a given elevation angle were set to the median value of data obtained for all azimuth angles. Thus, the results have become independent from the azimuth angle because buildings in the real world are usually not located regularly. These simulations were applied from 1 degree to 90 degrees for all elevation angles and a distribution was obtained as in Fig. 2.

Equation (1) depending on the elevation angle was obtained with the help of the data in Fig. 2.

\[ P_{LOS}(\theta) = 1 - \frac{t-n}{\theta-k} \]

Table 1 shows parameter change of equation 1 according to propagation environment.

<table>
<thead>
<tr>
<th>Propagation Medium</th>
<th>t</th>
<th>n</th>
<th>k</th>
<th>l</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suburban(SU)</td>
<td>101.6</td>
<td>0</td>
<td>0</td>
<td>3.25</td>
<td>1.241</td>
</tr>
<tr>
<td>Urban(U)</td>
<td>120</td>
<td>0</td>
<td>0</td>
<td>24.3</td>
<td>1.229</td>
</tr>
<tr>
<td>Dense Urban(DU)</td>
<td>187.3</td>
<td>0</td>
<td>0</td>
<td>82.1</td>
<td>1.478</td>
</tr>
<tr>
<td>Urban High-Rise(UHR)</td>
<td>352.0</td>
<td>-1.37</td>
<td>-53</td>
<td>173.8</td>
<td>4.670</td>
</tr>
</tbody>
</table>

Where \( P_{LOS}(\theta) \) is the probability of LOS in percent, \( \theta \) is an elevation angle in degrees and \( t,n,k,l,p \) are the empirical parameters given in Table I for the four typical environments.

III. OUR EMPIRICAL LOS PROBABILITY MODELLING APPROACH

Flat unobstructed path from the transmitter to the receiver is called free line of sight. Line of Sight is very important for transmitted signal in wireless communication. Even there is not line of sight in the signal path, the signal can still reach its target. Actually, if all transmitted signals move through free Line of sight path, the best propagation occurs. The high-frequency signals need more free line of sight path than the low frequency signals. Infrared communication is particularly sensitive to obstacles which is in the free LOS fields.

In this study, firstly, it was opened Trabzon data set which have binalar.shp, yollar.shp and mahalleleri.shp file. After that, they were compiled via ARCMAP module of ARCGIS software. The most well-known streets and avenues were selected in the city center of Trabzon, Turkey. After that, the buildings which is on the north side of these streets and at a certain distance from these streets were selected. Finally, various operations which use some ARCMAP tools were applied for selected buildings and streets. As a result of these processes, the knowledges such as the height of the buildings, the area occupied by the buildings, the edge lengths of the buildings and the distance to the road from buildings are extracted from the attribute tables which are obtained from Trabzon GIS dataset. It was created a Matlab algorithm that calculates LOS probability depending on the elevation angle for interested streets. Input variables of this algorithm are the height of the building, the edge lengths of the building and the distance from building to the road. Firstly, LOS probability was calculated for every building on the interested street. After that, Additive LOS probability which consists also building spaces.
was calculated and this additive LOS probability was added to pre-calculated LOS probability created by building. As a result of this, Elevation angle dependent LoS probability for interested street were estimated. When it was examined LOS probability graphs in this study, it has been seen that they are similar to some known probability distributions in the literature [25]. This study has been no analysis of similarity to known probability distributions in the literature [25].

A. ARCGIS and Trabzon City GIS Data

In this study, it was used ARCGIS 10.1 software version [6]. In ARCGIS software, basic file extension is ‘shp’. ‘Shp’ file extension name is obtained by shortening ‘shape’ word. The streets which LOS probability was calculated was created by using the necessary analysis and operations in ARCMAP. ARCGIS have many modules. The input data which will be entered to the the geometric-based algorithm is obtained by using ArcMap. Fig. 3 illustrates the ARCMAP module screenshots of Trabzon GIS data.

B. Our LOS Probability Model and Calculation Algorithm

LOS probability prediction models use Ray Tracing (RT) methods mostly. Ray tracing techniques are applications that require large computational load and time. Ray Tracing techniques is used in electromagnetics applications, radio communications, cellular communication systems, radar applications, image processing applications, etc. In RT, rays from transmitter are sent to all angles in medium and all calculations are accomplished.

LOS prediction algorithm in this study has geometrical approaches and it is flexible because it can be applied for all cities in Turkey. Firstly, LOS probability of every building in the street was calculated. After that, LOS probability of street was calculated by using LOS probability of every building. Finally, LOS probability of every street was combined conveniently according to the Bayes' conditional probability theorem [24]. After these operations, LOS probability of Trabzon city was calculated. The more streets taking into account for calculation, the more realistic the LOS probability values of Trabzon city will be obtained. Fig. 5 illustrates typical LOS scenario used in this study.

Fig. 4 illustrates a simple LOS scenario in Urban city. When Fig.4 is examined, it can be seen that there are buildings, trees and cars that prevent direct sight (LOS) between the transmitter and the receiver. They are common obstacles that may exist in all the typical urban-type settlements.
As seen in Fig. 5, Hi is observation height, Li is distance of LOS, $\theta_i$ is elevation angle, Gi is distance to the receiver from building edge which is parallel to road, ‘i’ is building index which helps to differentiate buildings from each other in the street and ‘e’ index represents elevation angle ranging from 1° - 90°. Relationship between elevation angle, $\theta_i$ and distance of LOS, Li can be stated as shown in equation (2).

$$\tan(\theta_e) = \frac{H_i}{G_i} \quad \text{and} \quad L_i = \sqrt{H_i^2 + G_i^2} \quad (2)$$

First, NLOS probability was calculated in this study. After that, LOS probability was calculated. Relationship between these probabilities was shown below.

$$S_{all} = S_{los} + S_{nlos} \quad (3)$$

where $S_{all}$ is total area of the interested region in square meters, $S_{nlos}$ is area of NLOS region in square meters, and $S_{los}$ is area of LOS region in square meters. Relation between area of regions is was given in equation (3). NLOS probability can be calculated by using equation (4).

$$P_{nlos} = \frac{S_{nlos}}{S_{all}} \quad (4)$$

where $P_{nlos}$ is NLOS probability.

Substituting $P_{nlos}$ in equation (4), LOS probability can be calculated using equation (6).

$$P_{los} + P_{nlos} = 1 \quad (5)$$

$$P_{los} = 1 - P_{nlos} \quad (6)$$

where $P_{los}$ is LOS probability.

C. Our LOS Probability Model and Calculation Algorithm for Trabzon City

After LOS probability of N number streets was calculated, LOS probability values depending on the elevation angle for Trabzon was obtained by utilizing Bayes' conditional probability theorem [24].

If elevation angle of between the receiver and the transmitter is known previously, LOS probability for Trabzon ($P_{los}$city) for arbitrary angle can be calculated using equation (7).

$$P_{los}(\theta_i) = \frac{1}{L} \sum_{n=2}^{N} L_i * P_{los}(L_i; \theta_i) \quad (7)$$

where $P_{los}(\theta_i)$ is LOS probability of Trabzon, $P_{los}(L_i; \theta_i)$ is LOS probability of i-th street when $\theta_i$ elevation angle between the receiver and the transmitter is known previously, $L_i$ is length of i-th street, $\theta_i$ is elevation angle, and $L$ is total length of N number streets (given by equation (9)).

The clearest expression of equation (7) is given by equation (8).

$$P_{los}(\theta_i) = \frac{L_1 * P_{los}(L_1; \theta_i) + L_2 * P_{los}(L_2; \theta_i) + \ldots + L_N * P_{los}(L_N; \theta_i)}{L} \quad (8)$$

$L$ in equation (7) and (8) can be calculated as below:

$$L = L_1 + L_2 + L_3 \ldots \ldots + L_N \quad (9)$$

In above equations, $L_i$ and $L$ are easily obtained by using ARCGIS attribute tables.

D. Our LOS Probability Graphics for Trabzon street and city

In this section, LOS probability figures vs. elevation angle were presented for four streets. The LOS probability figures were plotted in Matlab software. LOS probability of four streets were given this section (Fig. 6, Fig 7, Fig. 8 and Fig. 9). After that, LOS probability figure of Akif Saruhan street was examined and discussed. Fig.6 illustrates LOS probability figure vs. elevation angle of Akif Saruhan street.

Fig. 6 illustrates LOS probability figure vs. elevation angle of Akif Saruhan street. Fig. 7 illustrates LOS probability figure vs. elevation angle of Deliklitaş street. Fig. 8 illustrates LOS probability figure vs. elevation angle of Ahmet Barutçu Küütphanesi street. Fig. 9 illustrates LOS probability figure vs. elevation angle of Moloz street. Fig. 10 illustrates LOS probability figure vs. elevation angle of Trabzon city.

![Fig. 6. LOS probability of Akif Saruhan street](image-url)
To illustrate, when LOS probability figure in Fig. 6 is examined, it is clear that even if elevation angle is very low, LOS probability of Akif Saruhan street value is about 0.55. This indicates good quality of wireless communication at low elevation angles.

When LOS probability figure in Fig. 10 is examined, it can be understood clearly that even if elevation angle is very low, LOS probability of Trabzon city is about 0.25. This indicates that low quality of wireless communication at low elevation angles. LOS probability of Trabzon at low elevation angles is low because of Trabzon’s irregular building structures and settlements. It can be seen clearly that LOS probability figures in this study show similarities with other LOS probability figures in [12] and the other studies in literature.

IV. CONCLUSIONS AND SUGGESTIONS

Trabzon GIS data was analysed by using ARCIS software. As a result of this analyses, it was obtained building heights, road, street widths, distances between buildings, building floor area, etc. These obtained knowledges were used as an input data for geometrical algorithm and LOS probability of interested streets in Trabzon city were calculated.

As a future study, it will be investigated that the LOS probability values complies with which well-known cumulative distributions. As result of this, empirical formulas which represents LOS probability depending on the elevation angle will be derived. Instead of flat terrain in this study, rough terrain can be taken into account. LOS probability values obtained in this study can be used for HAPs propagation modelling and wireless channel modelling in Trabzon.

REFERENCES


A Simple State Observer Design for Linear dynamic Systems by Using Taylor Series

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Abstract— In this study, an estimation algorithm is proposed to estimate the state variables of linear time-invariant multi input-multi output systems. The proposed recursive algorithm is based on the orthogonal Taylor series approximation and uses some important properties of the Taylor series. It has an analog solution which can be obtained easily by a computer program. It is not affected by rounding errors. When the number of elements of series is sufficiently large, the Taylor series approximation gives results very close to exact solution.

Keywords -- State Estimation, Taylor series, State Observers, Curve fitting

I. INTRODUCTION

State variables that determine a system’s dynamics should be known for analysis and control of dynamical systems [1,2]. Specifically, dynamics feedback for pole placement is required. Furthermore, estimation of state variables in real time is a very important problem in adaptive control applications [3]. Unfortunately, all of the state variables cannot be measured in practice. As a result, use of a suitable state observer or estimator is unavoidable in order to obtain immeasurable state variables. There exit a variety of state observers in the literature [4,5]. Implementation of state observers that use only input and output measurements of the systems are carried out via solution of the observer state integral equations pertinent to the observer. There are several numerical solution algorithms for a solution of the observer state integral equations in the literature [6]. Even though the Runge-Kutta numerical integration algorithm is frequently used for this purpose, it has several drawbacks that depend on the step-size h. First, accuracy gets poorer as h increases. Second, computation time becomes an issue if h is too small. Third, round-off errors may become important for small values of h because the number of cycles required to cover the desired time interval [0,t] increases. Note that equations are evaluated for each t in the interval [0,t] in all of the above mentioned algorithms.

In this study, a simple general algorithm is proposed for state variables estimation of linear, time-invariant multi-input multi output systems. The proposed algorithm is based on Taylor series approximation and has an analog solution. The solution that results from the proposed algorithm gets closer to the true solution when more and more terms are kept in the Taylor series. Finally, the proposed method gives the approximate solution of the estimation vector $\hat{x}(t)$ as a function of time in the interval [0,t]. Consequently, computation of the state integral equations for each t is eliminated. The Taylor series are defined on the interval $t\in[0,1]$ and have the orthogonality property like the Walsh, Chebyshev and Legendre series [7,8]. The proposed algorithm uses some important properties such as the operational matrix of integration for Taylor vector [9,10]. The algorithm consists of four steps. In the first step, the feedback gain matrix $G$, which will force the estimation error to go to zero in a short time, is determined by using a suitable method [4]. In the second step, the observer state equation is converted into integral equation by integrating the terms on either side of the equation. After some algebraic manipulations, the time dependent terms on either side of the integral equation are removed. Hence, the problem is reduced to a set of nonlinear equations with constant coefficients. System outputs are used by the observer equations. Therefore, we have to calculate it’s as the function of time. They can obtained from plant output measurement by using curve fitting methods such as Linear Least Squares, Levenberg-Marquardt and Gauss-Newton [11]. Finally, in the last step, nonlinear equations for unknown state vector are converted into a recursive form whose solution can be obtained easily by a computer program. The proposed estimation algorithm was implemented in MATLAB™ and it was applied to different cases. Results obtained by the proposed algorithm are in harmony with the real results.

II. PROPERTIES OF THE TAYLOR POLYNOMIALS

The Taylor series expansion of an analytic function $f(t)$ in the neighborhood of the point $t=t_0$ can be written as

$$f(t) = f(t_0) + a_1(t-t_0) + a_2(t-t_0)^2 + \ldots + a_k(t-t_0)^k + \ldots$$ (1)
Thus, substituting Eq. 1 relation the following equalities can easily be obtained:

\[ f(t) = \sum_{k=0}^{r} a_k \lambda_k(t) \] (3)

where \[ \lambda_k(t) = t^k \] (4)

By truncating the series given in Eq. (3) after the \((r+1)\)th term, the approximate analytic function \(f(t)\) can be written as

\[ f(t) \approx \sum_{k=0}^{r} a_k \lambda_k(t) = a^T \lambda(t) \] (5)

where \(a\) and \(\lambda(t)\) are the Taylor polynomial coefficient vector and the Taylor series basic vector, respectively defined as

\[
a^T = [a_0, a_1, ..., a_r, 1]
\]

\[
\lambda^T(t) = [\lambda_0(t), \lambda_1(t), ..., \lambda_r(t)] = [1, t, ..., t^{r+1}]
\]

The Taylor series basic functions satisfy the following recurrence relations:

\[ \lambda_k(t) = t \lambda_{k-1}(t), \quad k=1,2, ..., r-1. \] (8)

Also, one may easily show that

\[ \int_0^t \lambda_k(t) \, dt = \frac{t^{k+1}}{k+1} \lambda_{k+1}(t). \] (9)

By using expression (3), the definite integral of an analytic function \(f(t)\) in the interval \((0,t)\) can be approximated as

\[ \int_0^t f(t) \, dt \approx \sum_{k=0}^{r-1} \int_0^t a_k \lambda_k(t) \, dt \]

\[ \approx \sum_{k=0}^{r-1} \left( \frac{a_k}{k+1} \right) \lambda_{k+1}(t) \sum_{k=0}^{r} b_k \lambda_k(t) \] (10)

where \(b_k, \quad k=1,2, ..., r\) are real numbers. From the last relation the following equalities can easily be obtained

\[ b_0 = a_0, \quad b_1 = \frac{(a_1)}{2}, ..., \quad b_r = \frac{(a_r)}{r}. \] (11)

Thus, substituting Eq. (11) in Eq. (10) leads to

\[ \int_0^t f(t) \, dt \approx a^T \mathbf{P} \dot{x}(t) \] (12)

where the square matrix \(\mathbf{P}\) is called the Taylor series operational matrix of integration, and is given by

\[
\mathbf{P} = \begin{bmatrix}
0 & 1 & 0 & 0 & \ldots & 0 & 0 \\
0 & 0 & 1/2 & 0 & \ldots & 0 & 0 \\
0 & 0 & 0 & 1/3 & \ldots & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\
0 & 0 & 0 & 0 & \ldots & 1/(r-2) & 0 \\
0 & 0 & 0 & 0 & \ldots & 0 & 1/(r-1) \\
0 & 0 & 0 & 0 & \ldots & 0 & 0 \\
\end{bmatrix}
\]

in the unique form. It can easily be shown that k-fold integration of \(\mathbf{P}\) is \(\mathbf{P}^k\) [16, 17]. The matrix \(\mathbf{P}\) of size r x r in Eq. (13) is called the integration operation matrix.

III. THE PROPOSED ESTIMATION ALGORITHM

The proposed estimation algorithm can be considered as state observer and its simulation diagram is given in Fig. 1.

![Figure 1. Simulation diagram representation of a state estimator](image)

State and error equations for the state observer shown in Figure 1 are

\[ \dot{x}(t) = M \dot{x}(t) + Bu(t) + Gy(t) \] (14)

\[ e(t) = Me(t), \quad e(0) = x(0) - \dot{x}(0) \] (15)

where

\[ M = (A - GC) \] (16)

In Eq. (14) and (15), \(\dot{x}(t), \dot{u}(t), e(t)\) and \(y(t)\) are the nx1 estimation vector, mx1 input vector nx1 error vector and...
px1 output vector, respectively. \(A, B, C\) and \(G\) are nxn state matrix, nxm input matrix, pnx output matrix and nxp gain matrix, respectively. The gain matrix \(G\) is effective only if \(x(0) \neq \hat{x}(0)\) and it should be chosen such that the estimation error goes to zero in a short period of time. The elements of the gain matrix \(G\) can be determined form the characteristic equation given in (17) by using arbitrary eigenvalues of \((A-GC)\) denoted \(\alpha_1, \alpha_2, \ldots, \alpha_n\) (note that eigenvalues are chosen such that \(e(t)\) goes to zero as quickly as possible) (Kailath, 1980):

\[
[\alpha I - (A - GC)] = 0 \tag{17}
\]

In Eq. (17), \(I\) is nxn identity matrix. Now, let us consider the estimation of \(\hat{x}(t)\). If we integrate both side of Eq. (14) we obtain

\[
\dot{\hat{x}}(t)-\hat{x}(0) = \int_0^t \dot{\hat{x}}(\tau)d\tau = \int_0^t B\hat{x}(\tau)d\tau + \int_0^t G\gamma(\tau)d\tau \tag{18}
\]

Let us assume that \(\dot{\hat{x}}(t), u(t), \hat{x}(0)\) and \(y(t)\) are continuous functions for \([0,t]\). Then, their Taylor series approximations can be given as

\[
\hat{x}(t) = \begin{bmatrix} x_{10} & x_{11} & \ldots & x_{1,n-1} \\ x_{20} & x_{21} & \ldots & x_{2,n-1} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n0} & x_{n1} & \ldots & x_{n,n-1} \end{bmatrix} + \begin{bmatrix} \lambda_1(t) \\ \lambda_2(t) \\ \vdots \\ \lambda_n(t) \end{bmatrix} = \hat{X}(t)\lambda(t) \tag{19}
\]

where

\[
\hat{X} = \begin{bmatrix} \hat{x}_0 & \hat{x}_1 & \ldots & \hat{x}_{r-1} \end{bmatrix}
\]

\[
\hat{x}_k = \begin{bmatrix} \hat{x}_{1k} & \hat{x}_{2k} & \ldots & \hat{x}_{nk} \end{bmatrix}^T, \quad k=0,1,2,\ldots,r-1
\]

\[
\hat{x}(0) = \begin{bmatrix} \hat{x}_1(0) & 0 & \ldots & 0 \\ \hat{x}_2(0) & 0 & \ldots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ \hat{x}_n(0) & 0 & \ldots & 0 \end{bmatrix} + \begin{bmatrix} \lambda_1(t) \\ \lambda_2(t) \\ \vdots \\ \lambda_n(t) \end{bmatrix} = \hat{X}\lambda(t) \tag{21}
\]

where

\[
\hat{X}_0 = \begin{bmatrix} \hat{x}_0 & 0 & \ldots & 0 \end{bmatrix}
\]

\[
\hat{x}(0) = \begin{bmatrix} \hat{x}_0(0) & \hat{x}_1(0) & \ldots & \hat{x}_n(0) \end{bmatrix}^T
\]

\[
\hat{u}(t) = \begin{bmatrix} u_{10} & u_{11} & \ldots & u_{1,r-1} \\ u_{20} & u_{21} & \ldots & u_{2,r-1} \\ \vdots & \vdots & \ddots & \vdots \\ u_{n0} & u_{n1} & \ldots & u_{n,r-1} \end{bmatrix} \lambda(t) = U\lambda(t) \tag{23}
\]

where \(U = \begin{bmatrix} u_0 & u_1 & \ldots & u_m \end{bmatrix}\)

\[
u_k = \begin{bmatrix} u_{ik} & u_{2k} & \ldots & u_{mk} \end{bmatrix}^T, \quad k=0,1,2,\ldots,r-1
\]

\[
y(t) = \begin{bmatrix} y_0 & y_1 & \ldots & y_{pk} \end{bmatrix}^T, \quad k=0,1,2,\ldots,r-1
\]

Output vector, \(y(t)\) can be obtain from output measurements by using curve fitting methods (Steven and Raymond, 2009). If we substitute Eq. (19), (21), (23) and (24) in Eq. (18), we have

\[
\hat{X}\dot{\lambda}(t)-\dot{X}\lambda(t) = \int_0^t \hat{X}\dot{\lambda}(\tau)d\tau + \int_0^t B\dot{\lambda}(\tau)d\tau + \int_0^t G\gamma(\tau)d\tau \tag{25}
\]

From Eq. (12), Eq. (25) can be written as

\[
(\hat{X}\dot{X})\lambda(t) = M\dot{\lambda}(t) + B\lambda(t) + G\gamma(\lambda(t)) \tag{26}
\]

If we remove the time-dependent terms in Eq. (26), the following set of constant coefficient algebraic equations is obtained

\[
\hat{X}\dot{\lambda} = M\dot{\lambda} + B\lambda + G\gamma \tag{27}
\]

The unknown coefficient vectors \(\hat{x}_i, i=0,1,2,\ldots,r-1\) in Eq. (27) are in a complex form. Hence, we need to rearrange Eq. (27). After applying the steps given in Appendix A, the following recursive equations are obtained

\[
\begin{cases}
\hat{x}_{i,0} = \hat{x}_i(0) + f_{i,0} \\
\hat{x}_{i,k} = \left( \frac{1}{k} \sum_{j=1}^{n} (m_i \hat{x}_{j,k-1}) + f_{i,k} \right), \quad i = 1,2,\ldots,n, \quad k=2,3,\ldots,r
\end{cases} \tag{28}
\]
The unknown estimation vectors $\hat{x}_i$, $i=0,1,2,...,r-1$ are obtained by using a computer program. Then, these vectors are substituted in Eq. (19), and the Taylor series approximation of the estimation vector $\hat{x}(t)$ is obtained. For the special case in which $G$ is zero matrix, the algorithm behaves as an open-loop observer. Since the observer error dynamics in open-loop observers is determined by eigenvalues of the system, the system must be asymptotically stable for convergence (Kailath,1980). The proposed estimation algorithm was implemented in MATLAB™ and was applied to different examples.

IV. NUMERICAL APPLICATIONS

Example 1. Consider a system having state equations given by

$$\dot{x}(t) = \begin{bmatrix} 1 & 1 \\ -2 & -3 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$$

$$y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} x(t)$$

This system has an analytical solution, which can be obtained from the unit-step input response as

$$\begin{bmatrix} x_1(t) \\ x_2(t) \end{bmatrix} = \begin{bmatrix} 2e^{-t} - e^{-2t} & e^{-t} - e^{-2t} \\ 2(-e^{-t} + e^{-2t}) & -e^{-t} + 2e^{-2t} \end{bmatrix} \begin{bmatrix} x_1(0) \\ x_2(0) \end{bmatrix} + \begin{bmatrix} (1/2)e^{-t} + (1/2)e^{-2t} \\ e^{-t} - e^{-2t} \end{bmatrix}$$

From Eq. (17), the gain vectors $[-1 \ 2]^T$, $[1 \ -1]^T$ and $[17 \ 47]^T$ are computed to place eigenvalues of the observer error $p$ at -1 , -2 and -10 , with multiplicity 2 respectively. The analytical expression of $y(t)$ given by Fig. 2 is obtained by using Linear Least Squares curve fitting method as follows:

$$y(t)=0.0266x^2-0.1184x^3+0.3089x^4-0.5827x^5+0.75x^6$$
$$-0.5x^7+0.5, \ for \ 0\leq t<1$$
$$y(t)=0.0021x^2-0.0123x^3+0.0347x^4-0.585x^5+0.043x^6$$
$$+0.0487x^7+0.3838, \ for \ 1\leq t<2$$
$$y(t)=0.0021x^2-0.0013x^3+0.0029x^4-0.0008x^5$$
$$-0.0155x^6+0.0493x^7+0.4415, \ for \ 2\leq t<3$$
$$y(t)=-0.0002x^2+0.0025x^3-0.0099x^4+0.0224x+0.4764, \ for \ 3\leq t<4$$
$$y(t)=-0.0002x^4+0.0013x^2-0.0042x^2+0.0088x+0.491, \ for \ 4\leq t<5$$
$$y(t)=-0.0001x^4+0.0005x^2-0.0016x^2+0.0033x+0.4967, \ for \ 5\leq t<6$$
$$y(t)=0.0002x^2-0.0006x^2+0.012x+0.4988, \ for \ 6\leq t<7$$
$$y(t)=-0.0002x^2+0.0004x+0.4995, \ for \ 7\leq t<8$$

From above expressions for each time subinterval Taylor series approximation coefficient matrix, $Y$ is obtained easily. For example we can write for $0\leq t<1$

$$Y=\begin{bmatrix} 0.5 & -0.5 & 0.7499 & -0.5827 & 0.3089 & -0.1184 & 0.02664 \end{bmatrix}$$

![Figure 2. Output curve for example 1.](image-url)

The analytical solution as well as solution obtained by the proposed algorithm curves for each gain vectors and for unit step input function are given in Figure 3. The initial value of estimation vector, $\hat{x}(0)$ is chosen as zero. In addition the estimation error curves are given in Figure 4. It can be seen that from Figure 3, as eigenvalues of the observer error $p$ move to the left in the left half s-plane, the estimation error curves converge to the zero in a shorter time. Estimation error of the proposed algorithm as a function of time for several values of $r$ is illustrated in Figure 5 from which one can see that estimation error decreases as $r$ increases.
Example 2. Consider a 2 input/1 output dynamic system described by the following state equation:

\[
\begin{bmatrix}
-1 & -1 \\
2 & 0
\end{bmatrix}
\begin{bmatrix}
x(t) \\
\dot{x}(t)
\end{bmatrix}
+ 
\begin{bmatrix}
1 \\
1
\end{bmatrix}
\begin{bmatrix}
u(t)
\end{bmatrix}
= 
\begin{bmatrix}
y(t) \\
x(t)
\end{bmatrix}
\]

By using Eq. (17), feedback gain matrices corresponding to the eigenvalues of the observer error dynamic (at -1, -2 and -5 with multiplicity, respectively) are computed as

\[
\begin{bmatrix}
0.42 \\
0.71
\end{bmatrix}, 
\begin{bmatrix}
0.14 \\
1.42
\end{bmatrix}, \text{ and } 
\begin{bmatrix}
5.28 \\
1.85
\end{bmatrix}
\]

The analytical expression of \( y(t) \) is obtained similar fashion to example 1 from Fig. 6. Thus, Taylor series approximation coefficient vectors are obtained easily for each time subinterval. For example, we can obtain in the interval \( 0 \leq t < 1 \):

\[
\begin{bmatrix}
0.009 & 21.43 & -92.11 & 188.7 & -211 & 126.6 & -31.77
\end{bmatrix}
\]

Simulation results of the observer and the proposed algorithm for each gain matrix and for unit step input functions are given in Figures 7 and 8. Here, the initial value of estimation vector, \( \hat{x}(0) \) is chosen as zero. The Runge-Kutta numerical solution method with \( h=0.01 \) was used for the observer simulation. In the estimation...
algorithm one can deduce from Figure 7 and 8 that the proposed Taylor series approximation based estimation algorithm gives state curves, that are very close to those of the observer when the number of terms in the Taylor series is sufficiently large. Like the results obtained in Example 1, as eigenvalues of the observer move to the left in the left half s-plane, the estimation error decreases.

Estimation error of the proposed algorithm as a function of time for several values of r is illustrated in Figure 9. It is obvious from Figure 9 that estimation error decreases as r increases.
V. CONCLUSION

In this study, a direct analytical algorithm based on the truncated Taylor polynomials and the operational matrix of integration has been suggested to estimate the elements of the state vector for a linear time-invariant multi input multi output system. The algorithm uses the Taylor series approximations of the observer in terms of the unknown coefficients of the state vectors. Thus, integration problem is reduced to solving a set of complex linear equations with constant coefficients. The equations for the solution of unknown coefficients are in a complex form. The algorithm we propose transforms these complex equations to a form, which is solved easily in a recursive manner. Furthermore, the algorithm can be easily implemented by using a computer program. The proposed technique does not suffer from the issues such as a choice of the step-size and the rounding errors that are present in the numerical integration algorithms. Proposed algorithm gives the solution of \( \hat{x}(t) \) as an analytical function of time in the interval \( t \in [0,t_{\text{max}}] \). As a result, numerical computation of the \( \hat{x}(t) \) for each \( t \) in the interval \((0,1)\) is eliminated.

For the special case in which the gain matrix \( G \) is chosen as zero matrices, very small number of operations will be sufficient for the solution since the algorithm behaves like an open-loop estimator. However, the system has to be asymptotically stable for convergence since the eigenvalues of the matrix \( A \) determine the observer error dynamics.

Numerical examples illustrate the fact that exact and approximated values of the state variables are in good agreement.

REFERENCES


SHORT CIRCUIT ANALYSIS IN ISLAND MODE USING ETAP

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Abstract— the requirement of power is very much essential for the development of any country. The simulation and short circuit study of an electrical power system is performed on Electrical Transient Analyzer Program (ETAP). The output of short circuit studies are helpful in order to determine system configuration, protection equipment, system voltage levels, cables size, and switchgears, transformers and grounding. ETAP short circuit analysis software analyzes the effect of 3-phase, 1-phase, line-to-ground, line-to-line, and line-to-line-to-ground fault currents on electrical power systems. In this research, selected a city where a national network connected with four distributed generation. This distributed generation was operated depending upon solar energy, wind power, waterpower and natural gas. In the normal case, the national network operates in parallel with the solar station and the wind station to feed all loads in the city. But, in the case of national network outage from city, feed only task loads in the city in island mode through these four distributed generation. With priority given to the work of the stations, the stations operates at the least cost of operating condition. Short circuit analysis can be done for the two cases mentioned above.

Keywords— Short circuit, ETAP, Distributed generation, Island mode, Grid.

I. INTRODUCTION

The short circuits happened in the electrical grid by the reasons of the urgency high voltage that over from the grid. Lot accidents appear in the general electric grid by this current for example (damage in the grid parts, firing or explosion in the breakers and in the lines).

One of practices to minimize the short circuits in the grid determine the fault region and treatment the problem without stopping the lines and to avoid the problem development.

The high sensitivity protection devices and the high response from the technicians help us to maintain the power supply [1].

In this paper using the ETAP software to illustrate the short circuits analysis and treatment it by simulation the single line diagram of the general grid connected with four distributed generation (wind, hydroelectric, photovoltaic energy and natural gas).

The major aims from applied the short circuits to select the appropriate equipment’s to avoid the accidents in the equipment’s and the employees with continuity power supply. And it collected in:

1) Determination of short-circuit duties on switching devices, that is, high-, medium-, and low-voltage circuit breakers and fuses
2) Calculation of short-circuit currents required for protective relaying and coordination of protective devices
3) Evaluations of adequacy of short-circuit withstand ratings of static equipment like cables, conductors, bus bars, reactors, and transformers
4) Calculations of fault voltage dips and their time-dependent recovery profiles [2].

In the power stations and the industrial facilities and the public buildings the designers take in consideration the safety procedures to maintain the equipment’s and the labour, and provide the systems high reliability in the control of systems parts.

The urgency short circuits in the systems leading to big losses also some person’s loss these lives or at less power supplies loss.

The short circuits caused the isolation collapse in the electrical parts and in some cases can see sparks in the short circuits points and these sparks caused fires in the locations. In first time of the short circuits occur the protection devices will work in the various parts and these devices distributed on the system or buildings parts.

The late response when the short circuits appear lead to raising risks to the systems and huge losses [3]. In the electrical power systems the short circuits happened between the phases itself or between the phases and the ground in this paper explain the four types of short circuits as following:

1) Three phase faults
2) Line to ground
3) Line to line
4) Line to line to ground

In the Electrical Transient Analyzer Program (ETAP) software determined the total short circuit currents in the generators, transformer, lines and the other parts of electrical systems.

ETAP depending on two standards the ANSI and IEC standards [4].
II. SINGLE LINE DIAGRAM

In this paper, four distributed generation working by the sun, wind, Hydroelectric and natural gas connected with the national grid. Single line diagram drawing by using ETAP program [5] shown in Figure 1.

In the normal case the solar station and the wind is working in parallel with the national grid to feed the loads. In the case of network outages, these stations operate in the island mode to feed the task loads.

III. SHORT CIRCUIT ANALYSIS

The short circuit analysis of distributed generation system using ETAP. The IEC standard is used to analyze the short circuit. In this simulation, choose all buses as a fault. ETAP short analysis of the 3-phase, 1-phase, phase-to-ground, phase-to-phase and phase-to-phase-to-ground can be realized [6].

1- Short Circuit Analysis With Grid

In this case the network, Solar Energy and Wind Energy has operated there. The 3-phase short circuit analysis shown in figure 2 [7].

<table>
<thead>
<tr>
<th>Bus</th>
<th>3-phase fault</th>
<th>L-G fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>kV</td>
<td>I&quot;k</td>
</tr>
<tr>
<td>Bus 1</td>
<td>0,4</td>
<td>138,9</td>
</tr>
<tr>
<td>Bus 2</td>
<td>0,6</td>
<td>150,3</td>
</tr>
<tr>
<td>Bus 3</td>
<td>6,6</td>
<td>11,6</td>
</tr>
<tr>
<td>Bus 4</td>
<td>6,6</td>
<td>10,3</td>
</tr>
<tr>
<td>Bus 5</td>
<td>33</td>
<td>10,6</td>
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<tr>
<td>Bus 6</td>
<td>33</td>
<td>9,1</td>
</tr>
<tr>
<td>Bus 7</td>
<td>33</td>
<td>7,7</td>
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<tr>
<td>Bus 8</td>
<td>33</td>
<td>8,8</td>
</tr>
<tr>
<td>Bus 9</td>
<td>33</td>
<td>14,8</td>
</tr>
<tr>
<td>Bus 10</td>
<td>33</td>
<td>23,2</td>
</tr>
</tbody>
</table>

Fig. 1 Single Line Diagram

Fig. 2 Three Phase Short Circuit

2- Short Circuit Analysis without Grid (Island Mode)

This mode of operation the network is outgoing, and the four distributed generation source are feed important loads only in the island mode [8]. The 3-phase short circuit analysis shown in figure 3.

<table>
<thead>
<tr>
<th>Bus</th>
<th>3-phase fault</th>
<th>L-G fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>kV</td>
<td>I&quot;k</td>
</tr>
<tr>
<td>Bus 1</td>
<td>0,4</td>
<td>101,5</td>
</tr>
<tr>
<td>Bus 2</td>
<td>0,6</td>
<td>95,5</td>
</tr>
<tr>
<td>Bus 3</td>
<td>6,6</td>
<td>8,0</td>
</tr>
<tr>
<td>Bus 4</td>
<td>6,6</td>
<td>7,3</td>
</tr>
<tr>
<td>Bus 5</td>
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</tr>
<tr>
<td>Bus 6</td>
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<td>2,1</td>
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<tr>
<td>Bus 8</td>
<td>33</td>
<td>2,1</td>
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<tr>
<td>Bus 9</td>
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<td>2,2</td>
</tr>
<tr>
<td>Bus 10</td>
<td>33</td>
<td>2,2</td>
</tr>
</tbody>
</table>
The Line to line short circuit analysis shown in figure 4.

The Line to line to ground short circuit analysis shown in figure 6.

The Line to ground short circuit analysis shown in figure 5.
Definition of Terms
IEC standards use the following definitions, which are relevant in the calculations and outputs of PowerStation.

- **Initial Symmetrical Short-Circuit Current (I”k)**
  This is the rms value of the ac symmetrical component of an available short-circuit current applicable at the instant of short-circuit if the impedance remains at zero time value.

- **Peak Short-Circuit Current (ip)**
  This is the maximum possible instantaneous value of the available short-circuit current.

- **Symmetrical Short-Circuit Breaking Current (Ib)**
  This is the rms value of an integral cycle of the symmetrical ac component of the available short-circuit current at the instant of contact separation of the first pole of a switching device.

- **Steady-State Short-Circuit Current (I_k)**
  This is the rms value of the short-circuit current which remains after the decay of the transient phenomena.

IV. CONCLUSION
The errors determine and data analysis in the power systems help the industrial facilities to determine and support the appropriate protection devices and calculate the minimum and maximum value of the system parts to assurance high safety level.

ETAP software applied in the power systems to make simulation and to maintain the equipment’s and the people lives and the rid on from the short circuits risks.
All the studies in the ETAP applied the various types of the short circuits in the (AC) and (DC) systems
1) I”K (initial AC symmetrical SC current)
2) ip (peak SC current)
3) I_k (study state SC current)
ETAP found the acceptable results for the above types.
The gathering information for the short circuit currents helpful to determine the limits value for the voltage, the protection, transformers, lines or cable and the other system parts.

REFERENCES
Transmission and Reflection Characteristics of Fourfold Rotationally Symmetric Rectangular Nanoaperture Antenna Arrays

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Abstract—The geometrical dependence of metallic nano-patterns provides adjustable resonance frequencies. Especially, aperture-based nanostructures exhibit resonant behaviors in transmission phenomena with easily accessible ultra-high-field localization characteristics and aperture dimensions influence the spectral response of the structure. We report the transmission and reflection characteristics of fourfold rectangular shaped nanoaperture antennas that exhibit high near field distributions in the mid-infrared regime. Numerical analyses are carried out by using finite-difference-time-domain method to analyze the transmittance and reflectance spectra of the structure. We investigate the geometrical parameters that can enable fine control of the resonance frequencies and tunable optical characteristics are concluded by the parameter sweeps. High SEIRA (surface enhanced infrared absorption) enhancement at resonant wavelength and resonant behavior in mid-infrared regime ensure that the proposed antenna can be utilized for infrared detection applications.

Keywords—Plasmonics, sensors, subwavelength structures, nanostructures, spectroscopy, infrared

I. INTRODUCTION

Dependence on the geometrical parameters of metallic nano-patterns provides adjustable resonance frequencies as observed from the theoretical and experimental studies. Recently, particle- and aperture-based nanoantennas with different geometries have been studied to capture, control and manipulate the light at the preferred wavelengths [1-6]. Especially, aperture-based nanostructures has been the subject of several researches due to their resonant behavior in transmission phenomena with easily accessible ultra-high-field localization characteristics and it has been showed aperture dimensions influence the spectral response of the structure [2-6].

In this study, we present the transmission characteristics of a fourfold rotationally symmetric rectangular nanoaperture antenna arrays operating in the mid-infrared regime. The transmittance spectra of the structure are investigated by using the finite-difference time-domain (FDTD) method [7]. We obtain the field distributions at the resonant wavelength, which indicates the physical origin of the resonant modes. We analyze the parameters that can enable fine control of the resonance frequencies of the structure. High SEIRA (surface enhanced infrared absorption) enhancement [8] at resonant wavelength and resonant behavior in mid-infrared regime ensure that the proposed antenna can be utilized for infrared detection applications.

II. NUMERICAL ANALYSES

Fig. 1 The schematic view of the unit cell: (a) Top view (aperture width W, aperture length H, the width the central square aperture C, the geometrical interference of the rectangles with central square S, periodicities Px and Py), and (b) cross-section view.

Fig. 1 shows a schematic structure of the unit cell of the proposed nanoaperture antenna array. In this figure, W is rectangular aperture width, H is rectangular aperture length, C is the width the central square aperture, S is the geometrical interference of the rectangles with central square, and Px and Py are periodicities of the structure. During the simulations, the unit cell of the proposed resonator antenna array is modeled on a free-standing 100-nm-thick silicon nitride (SiN,) substrate. For the metal overlay, a 30-nm-thick Au layer and a 5-nm-thick Ti adhesion layer are added onto the
dielectric substrate. Excitation the surface plasmon modes on the resonator by $E_x$-polarized normally incident electromagnetic field is simulated. The dielectric constants of the metals used for simulation are taken from Ref. [9]. Periodic boundary conditions are chosen as $x$- and $y$-axes, and perfectly matched layers are used along the $z$-axis. Unless otherwise indicated, the analyses are executed under the $x$-polarization and geometrical parameters are chosen as $C = W = 200$ nm, $H=800$ nm, $P = P_x = P_y = 2000$ nm, and $S = 50$ nm.

![Fig. 2 Transmittance spectra of the structure (a) $C$ variation, (b) $H$ variation, (c) $P$ variation, (d) $S$ variation, and (e) $W$ variation.](image)

To control the spectral response of the proposed nanoaperture arrays, a number of numerical studies are performed to obtain a fine tuning control mechanism for the spectral response of the structure (Fig. 2) versus different parameter sweeps. Fig. 2 shows the transmission spectra of fourfold rectangular shaped aperture arrays for different parameter sweeps. As can be seen from Fig. 2a, resonant wavelength red-shifts while increasing central aperture width $C$. Resonant wavelength red-shifts and transmittance increases significantly while increasing rectangular aperture length, $H$ (Fig. 2b). Fig. 2c shows that there is a small blue-shift in resonant frequency and transmittance changes mostly with increasing periodicity $P$. The changing in the geometrical interference of the rectangles with central square $S$ ensures only a significant frequency shift as observed from Fig. 2e.

![Fig. 3 Reflectance spectra of the structure (a) $C$ variation, (b) $H$ variation, (c) $P$ variation, (d) $S$ variation, and (e) $W$ variation.](image)

Spectral reflectance is also investigated numerically for the proposed nanoaperture design which can operate in reflection mode in order to obtain a fine tuning control mechanism (Fig. 3) versus different parameter sweeps in Fig. 2. As can be seen from Fig. 2a, resonant wavelength red-shifts while increasing $C$. Resonant peak red-shifts and reflectance decreases significantly while increasing $H$ (Fig. 2b). Fig. 2c shows that there is a small blue-shift in resonant frequency and transmittance changes mostly with increasing $P$. Changing $S$ ensures only a significant frequency shift (Fig. 2d). Increasing $W$ leads to frequency red-shift as observed from Fig. 2e.

To detect the reason of resonant mode, we analyze near field distribution on metal-air interface and two critical vertical surface of the unit cell. Fig. 4 shows the near-field analyses of the structure. Frequency of the resonant peak is $f_{res}=57.1$ THz ($\lambda_{res}=5247.2$ nm, $\nu_{res}=1905.8$ cm$^{-1}$) and the SEIRA enhancement ($|E|^2/|E_{in}|^2$) at $f_{res}$ is $\sim11660$ for chosen parameters; $C = W = 200$ nm, $H=800$ nm, $S = 50$ nm and $P =$
2000 nm. This high intensity enhancement at resonant peak is required for increasing sensing resolution and sensor-analite interaction in sensing applications.

![Fig. 4 Distributions of SEIRA enhancements |E|^2/|E|^2]. (a) at air - metal interface (z = 30 nm) from the horizontal field monitor, and (b) y = 50 nm and (c) y = 100 nm from the vertical field monitors (C = W = 200 nm, H=800 nm, S = 50 nm and P = 2000 nm).

III. CONCLUSIONS

In conclusion, we present the transmission and reflection characteristics of a resonator plasmonic nano-antenna based on fourfold rotationally symmetric rectangular shaped nanoaperture array which can be useful for infrared detection applications. We determined the behavior of the spectral response towards geometrical parameter variations. We revealed the physical provenance of the resonant behavior by SEIRA enhancements distribution analysis. Such nanoapertures with tunable spectral response can be capable for comprehensive consequences for infrared detection applications. The proposed nanoaperture design can support a high quality resonant mode with strong near-field enhancement.

ACKNOWLEDGMENT

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REFERENCES

Compare of Pilot Based and Semi-blind Channel Estimation Techniques in Multiple Input Multiple Output Communication Systems

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Abstract—Channel estimation algorithms can be grouped into three categories as pilot based, blind and semi-blind. In pilot based channel estimation, some of data symbols are used to estimate channel. In blind channel estimation statistical properties of channel are used. In semi-blind channel estimation information from both data symbols and statistical properties is utilized. In this study, pilot based semi-blind channel estimation are used to estimate the channels with various frequency and time selectivity in multiple input multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) systems. Semi-blind channel estimation is done by using independent component analysis (ICA). Simulation results show that if the channel to be estimated is frequency selective, semi-blind channel estimation technique can be used instead of pilot based channel estimation.

Keywords— MIMO-OFDM, pilot based, semi-blind, channel estimation, ICA.

I. INTRODUCTION

Multiple input multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) which has high spectral efficiency is the key technology of today’s wireless communication systems and it has become popular technique for transmission of signals over wireless channel [1-3]. In order to overcome the adverse effects of multipath fading in mobile communication channels, channel estimation must be performed. Channel estimation algorithms can be categorized into three groups. In pilot based channel estimation, value of previously known pilot bits are inserted into the transmitted signal is compared to the received value in the receiver and in pilot based channel estimation one dimensional pilot placement (block and comb) and two dimensional pilot placement (rectangular and diamond) are used. In blind channel estimation, algorithms often exploit the second-order stationary statistics with high computational complexity. Therefore blind channel estimation isn’t used frequently. In semi-blind channel estimation algorithms both small number of pilot bits and statistical properties of channel are used. In literature there are numerous channel estimation algorithms for example ICA [4], singular value decomposition (SVD) [5], subspace methods [6] and. All algorithms have advantages and disadvantages. But in semi-blind channel estimation, more bandwidth efficiency are obtained than pilot based channel estimation because of less pilot usage.

II. MIMO-OFDM CHANNEL

2x2 MIMO-OFDM communication system using Alamouti illustrated in Fig. 1.

Alamouti’s space time block coding for these structures is given equation 1.

\[
X = \begin{bmatrix}
 x_0 & x_1 \\
 -x_1^* & x_0^*
\end{bmatrix}
\]

(1)

A specific \(t\) time, \(x_0\) and \(x_1\) symbols are respectively transmitted simultaneously from the first and second antennas. The next time \((t+\tau)\), \(-x_1^*\) and \(x_0^*\) are transmitted respectively. The signals reach the receiving antenna at \(t\) and \(t+\tau\) time are given in equation (2-5).

\[
y_{11}(k) = x_0(k) H_{11}(k) + x_1(k) H_{21}(k) + n_{i1}(k)
\]

(2)

\[
y_{21}(k) = -x_1^*(k) H_{11}(k) + x_0^*(k) H_{21}(k) + n_{i2}(k)
\]

(3)

\[
y_{12}(k) = x_1(k) H_{12}(k) + x_0(k) H_{22}(k) + n_{i2}(k)
\]

(4)

\[
y_{22}(k) = -x_1^*(k) H_{12}(k) + x_0^*(k) H_{22}(k) + n_{i2}(k)
\]

(5)

Channel estimation coefficients in the receiver are obtained as shown in equation (6-9).
\[ \hat{H}_x(k) = \frac{x_y(k) - x_E y_m(k)}{|x_y(k)|^2 + |x_E(k)|^2} \]  
\[ \hat{H}_y(k) = \frac{x_y(k) + x_E y_m(k)}{|x_y(k)|^2 + |x_E(k)|^2} \]  
\[ \hat{H}_z(k) = \frac{x_y(k) - x_E y_m(k)}{|x_y(k)|^2 + |x_E(k)|^2} \]  
\[ \hat{H}_w(k) = \frac{x_y(k) + x_E y_m(k)}{|x_y(k)|^2 + |x_E(k)|^2} \]

**III. PILOT BASED CHANNEL ESTIMATION**

In this study a rectangular pilot placement (Fig. 2) is used for the estimation of MIMO channel.

![Fig. 2 Rectangular pilot placement](image)

In rectangular structure, pilot bits are placed periodically in the time and frequency domain. In the pilot based channel estimation, the values of the channel at the position of the pilot can be obtained using least squares (LS) and the minimum mean square error (MMSE) [7, 8].

**IV. SEMI BLIND CHANNEL ESTIMATION**

In this study a semi-blind algorithm is used for the estimation of frequency selective MIMO channel matrix \( H \). The ICA algorithm is based on a decomposition of the channel matrix \( H \). The aim of ICA is finding the \( x \) signals in equation (10).

\[ y = Hx \]  

For a good results there are two assumptions in ICA. First; source signals \( x \) are independent of each other. The second one is the values in each source signal have non-Gaussian distributions.

ICA’s preprocessing steps are:

1) **Centering:** In this step, the observation vector \( y \) by subtracting its mean vector \( m = E\{y\} \)
\[ y_c = y - m \]

2) **Whitening:** A simple method to perform the whitening transformation is to use the eigenvalue decomposition (EVD) [9] of \( y \). That is, decomposition the covariance matrix of \( y \) as follows:
\[ m = E\{yy^T\} = VDV^T \]  

where \( V \) is the matrix of eigenvectors of \( E\{yy^T\} \) and \( D \) is the diagonal matrix of eigenvalues. The observation vector can be whitened by the following transformation:
\[ y_w = VD^{-1/2}V^Ty \]
\[ y_w = VD^{-1/2}V^THx = H^*x \]

where \( H^* \) is the mixing matrix. Initial value of \( H^* \) is given randomly. Then with a using various algorithms (e.g. fixed point algorithm [10]), the last value of \( H^* \) has obtained.

**V. RESULTS**

In this study, pilot and semi-blind channel estimation are used to estimate the channels with various frequency selectivity. Firstly, two dimensional pilot based channel estimation is performed using rectangular pilot placement. Semi-blind channel estimation is done by using ICA with a 1.2 and 4 pilot bits. In simulations; 20MHz band width, ITU pedestrian (Ch1) and vehicular channels (Ch2), 200 Hz Doppler frequency, 2x2 MIMO structure and 1024 subcarriers are used.

In Figure 3 rectangular pilot placement and ICA based semi-blind channel estimation results are given for K1 channel. In rectangular placement different number of pilots (different pilot ratio (PR)) are used (PR=4, PR=16, PR=64, PR=256) and in ICA methods 1, 2 and 4 pilots are used. It is shown that pilot based channel estimation with a rectangular placement results are better than a semi-blind channel estimation results.

![Fig. 3 Performance of ICA and rectangular pilot placement for K1](image)
So for a pedestrian channel K1 which is less frequency selectivity channel than the vehicular channel K2, pilot based channel estimation results are better than the ICA results. Thus with a using a small number of pilot bits, best performance is obtained.

Pilot based with a rectangular placement and semi-blind channel estimation based ICA results for K2 are given in Figure 4. It is shown that up to 22 dB, rectangular pilot placement is better than the ICA. But after 22 dB, ICA (PR=4) is better than rectangular pilot placement.

VI. CONCLUSIONS
The results show that if the channel to be estimated is frequency selective and SNR>22dB, semi-blind channel estimation technique can be used instead of pilot based channel estimation technique which allows less pilot usage and consequently enhanced more bandwidth efficiency. So it is understood that pilot based channel estimation results aren’t always better than the semi-blind channel estimation results.

REFERENCES
Classification of Digital Modulation Signals with Time-Frequency Texture Features and Support Vector Machines

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Abstract—Automatic Modulation Classification (AMC) is carried out as a basic structure between signal detection and demodulation types. Detection of modulation type of a received signal is a challenging task in communication environment. Recently, AMC has gained a paramount importance especially in cognitive radio applications. Most of the AMC methods assume that additive white Gaussian noise contaminates the received signal. There might be degradation in the performance of the traditional modulation classification methods in the impulsive noise condition. In this study, firstly the digital modulation signals are transformed into t-f domain by Short Time Fourier Transform (STFT) and then by the Spectrograms of STFT are used to obtain the t-f images of digital modulation signals. We then use Gray-Level Co-occurrence Matrix (GLCM) method which includes some statistical texture recognition techniques as a feature based AMC. Finally, we use the Support Vector Machines (SVMs) classification technique for classifying the digital modulation types. We use 0, 5 and 10 dB noise levels, respectively. We implement the proposed scheme on MATLAB. QAM, 16-QAM, 32-QAM, 64-QAM, BPSK and 8-PSK signals are considered in the experiments. The method we propose achieves the classification with having very little performance loss in impulsive noise condition compared to the Gaussian noise condition.

Keywords—Automatic Modulation Classification, Statistical Texture Recognition, Support Vector Machines.

I. INTRODUCTION

With the rapid development of wireless communication technologies such as cognitive radio, spectrum surveillance, threat evaluation, interference identification and etc. use of automatic modulation classification (AMC) has gained much attention for both civil and military applications [1], [3]. AMC provides detection of the correct modulation type from the received waveforms having different distinctive characteristics [9]. In a general communication system, receiver knows the prior information including modulation type, carrier frequency, bandwidth, symbol rate, carrier phase, and etc. therefore, the received signal can be demodulated accordingly and then the data can be extracted. AMC, however, can recognize the modulation types without need to this prior information.

In a communication system, transmitted signal is exposed to the disruptive effects of the communication channel. One of the disruptive effects is noise in the environment. Most of the modulation classification algorithms are implemented under additive white Gaussian noise (AWGN) condition for the performance analysis. However, noise types in the communication channel occur as a mix of AWGN and impulsive noise characteristic [8]. The impulsive noise occurs as various natural and man-made sources caused by electromagnetic interference such as automotive ignitions, neon lights and etc. in communication channels and this situation decreases the performance of the classifiers used for AMC [5].

There are usually two methods called the statistical texture recognition and the decision theoretic approach for grouping the modulation classification schemes. In order to formulate the classification problem, probabilistic and hypothesis testing arguments are used in decision theoretic approach and with this way the classification rule can be formed. For it keeps the error rate classification in a minimum level, generally the solution is optimal. Need for prior information can be accepted as the disadvantage of this approach [6], [8].

Texture recognition methods, however, do not need such careful treatment, although choosing the right features set is still an issue. This classification method consists of two steps: the feature extraction subsystem and recognition subsystem. The feature extraction subsystem works as extracting distinctive characteristics that are called features from the receiver signal. Example of features used are higher-order cumulates, signal spectral is prepared from wavelet transform, Fourier transform, constellation shape, signal peaks, power moments etc. [2], [4], [6], [8].
The second subsystem, the texture recognition works as classifying the received signal based on the features extracted. It can be applied in many ways such as maximum likelihood classifier (MLC), K-nearest neighborhood classifier (KNN), artificial neural network (ANN), SVM, Genetic Algorithm (GA) etc. [7], [10]-[12].

In this study we propose feature based automatic modulation classifier using SVM for classification of modulation BPSK, 8-PSK, QAM, 16-QAM,32-QAM in the mix of Gaussian noise and Impulsive noise environment. We use time-frequency texture feature based on the presented GLCM. We also present probability of correct classification for different SNR value between -5 dB to 20 dB.

This paper is organized as follows: we focus on signal models and problem statement for digital modulation signals in Section II. STFT which transformed into t-f domain is explained in Section III. Feature extraction based on GLCM including specific distinctive statistic information is presented in Section IV. SVM for digital modulation classification is explained in Section V. Simulation result is represented in Section VI. Finally, conclusions are drawn in Section VII.

II. SIGNAL MODELS AND PROBLEM STATEMENT

In digital communication, a modulated signal can be generally represented as;

\[ s(t) = A_m G_T \cos(2\pi f_m(t) + \varphi_m(t)) \]  

where \( A_m, G_T, f_m \) and \( \varphi_m \) are the message amplitude, pulse shaping function, message frequency and message phase, respectively.

The received signal can be represented as;

\[ r(t) = s(t) + n(t) \]  

received signal is sum of the transmitted signals and noise signals. where \( s(t), r(t), n(t) \) transmitted signal, received signals and noise signal respectively.

The noise signal can be represented as;

\[ n(t) = w(t) + i(t) \]  

noise signal \( n(t) \) in our noise signal model occurs noise signal \( w(t) \) is the additive white Gaussian noise and \( i(t) \) is the impulsive noise added. The AMC algorithm needs to achieve the classification without being effected by the noise so that the signal coming to the receiver can recognize the modulation type correctly.

III. Spectrogram

The discrete time STFT of \( x[m] \) is defined as;

\[ X(n, \omega) = \sum_{m=-\infty}^{\infty} x[m]w[n - m]e^{-j\pi mn} \]  

The discrete STFT is defined as;

\[ X(n, k) = X(n, \omega)\left|_{\omega=\frac{2\pi k}{T}} \right. \]  

where the window function \( w[m] \) centered at time \( n \) is multiplied with the signal \( x[m] \) before the Fourier transform. The window function is viewing the signal just close to the time \( n \) and the Fourier transform will be an estimate locally around \( n \). The usual way of finding the STFT is to use a fixed positive even window, \( w[m] \), of a certain shape, which is centered around zero and has unity power. Similar to the ordinary Fourier transform and spectrum we can formulate the spectrogram as;

\[ S(n, k) = |X(n, \omega)|^2 \]  

which is used very frequently for analyzing time-varying and non-stationary signals.

IV. FEATURE EXTRACTION

GLCM is known as a popular texture encoder where directional patterns with a specific distance and angle between neighboring image pixel pairs are countered [15]. In other words, GLCM is a square matrix where the number of rows and columns is equal to the number of gray levels of input image [13].

Instead of using the GLCM directly, 20 popular statistical features are extracted from GLCM of input images. These features are autocorrelation, contrast, correlation, cluster prominence, cluster shade, dissimilarity, energy, entropy, homogeneity, maximum probability, sum of squares variance, sum average, sum variance, sum entropy, difference variance, difference entropy, information measure of correlation, inverse difference is homogeneity, inverse difference normalized, Inverse difference moment normalized, respectively.

V. SVM CLASSIFIER

The SVM is a machine-learning algorithm, which uses a flexible representation of the class boundaries in order to solve the classification problems [14]. Given a set of training samples, each marked samples for belonging to one of two classes, a SVM training algorithm builds a model that assigns new examples into one class or the other. SVM model is a representation of the samples as points in space, mapped so that the samples of the separate classes are divided by a gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a class based on which side of the gap they fall on [12].
VI. SIMULATION RESULTS AND DISCUSSION

All digital modulation signals are simulated according to Eq. (1), Eq. (2) and Eq. (3) in MATLAB. The simulation parameters are tabulated in Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Frequency, $f_s$</td>
<td>1Mhz</td>
</tr>
<tr>
<td>Carrier frequency, $f_m$</td>
<td>2Khz</td>
</tr>
<tr>
<td>Baud Rate, $R_b$</td>
<td>1000 baud</td>
</tr>
<tr>
<td>No symbol, $N_s$</td>
<td>64/128/256 symbols</td>
</tr>
</tbody>
</table>

All the data formed in the simulation is normalized. Normalization coefficients for different modulation types are given in Table II.

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Scaling Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK, 8PSK, QAM</td>
<td>1</td>
</tr>
<tr>
<td>16-QAM</td>
<td>$1/\sqrt{10}$</td>
</tr>
<tr>
<td>32QAM</td>
<td>$1/\sqrt{20}$</td>
</tr>
<tr>
<td>64-QAM</td>
<td>$1/\sqrt{42}$</td>
</tr>
</tbody>
</table>

In simulations, the training and test datasets are constructed with various SNR values. As it was mentioned earlier, we use a mixed noise model where AWGN and impulsive noise are considered. An illustrative example is shown in Fig.1 where an 8-PSK signal was contaminated with the mixed noise model. The SNR of noise level is 15 dB. In addition, a similar illustration is shown for 32-QAM in Fig. 2.

After constructing the gray scale sub-images for digital modulation signals, the texture descriptors were computed. For computing the GLCM, the distance parameter set to 1 and the angle parameter set to the values ranging from 0° to 135° within a 45° increment. Thus, 4 GLCMs were obtained and by computing the contrast, correlation, energy and homogeneity features, a 20-dimensional feature vector was constructed for each sub-image. After concatenation procedure, 80-dimensional feature vector was obtained for each digital modulation signals. For SVM classifier, we experimented with all kernels, and the best result was obtained with radial basis function kernel. The C parameter was set to 10000.

The probability of correct classification for simulated data is shown in Fig. 3. The confusion matrices are also given in Table III and Table IV for Gaussian noise environment and mix of Gaussian noise and impulsive noise environment, respectively. The probability of correct classification for simulated data is more than 83% at 0 dB SNR in mix of Gaussian noise and impulsive noise environment.
TABLE III. CONFUSION MATRIX FOR SVM CLASSIFIER IN GAUSSIAN NOISE CONDITION

<table>
<thead>
<tr>
<th>Modulation</th>
<th>SNR=5dB</th>
<th>SNR=10dB</th>
<th>SNR=15dB</th>
<th>SNR=20dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK</td>
<td>58</td>
<td>20</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>8-PSK</td>
<td>15</td>
<td>68</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>QAM</td>
<td>14</td>
<td>25</td>
<td>61</td>
<td>0</td>
</tr>
<tr>
<td>16-QAM</td>
<td>0</td>
<td>0</td>
<td>82</td>
<td>10</td>
</tr>
<tr>
<td>32-QAM</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>64</td>
</tr>
<tr>
<td>64-QAM</td>
<td>1</td>
<td>0</td>
<td>32</td>
<td>44</td>
</tr>
</tbody>
</table>

TABLE IV. CONFUSION MATRIX FOR SVM CLASSIFIER IN MIX OF GAUSSIAN AND IMPULSIVE NOISE CONDITIONS

<table>
<thead>
<tr>
<th>Modulation</th>
<th>SNR=5dB</th>
<th>SNR=10dB</th>
<th>SNR=15dB</th>
<th>SNR=20dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK</td>
<td>43</td>
<td>22</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>8-PSK</td>
<td>15</td>
<td>63</td>
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</table>

VI. CONCLUSIONS

In this paper, we supervised signal feature based automatic modulation classification by using SVM classifier under mix of Gaussian noise and impulsive noise condition. For different modulation techniques including BPSK, 8-PSK, QAM, 16-QAM, 32-QAM, 64-QAM, the simulation results and confusion matrix are presented under different SNR values and magnitudes of impulse noises. We propose a method which achieves the classification in an accuracy similar to the performance in the Gaussian noise conditions without being effected by the impulsive noise. The AMC method we propose has an approximately 1% lower performance in impulsive noise condition compared to the Gaussian noise condition. The proposed system provides a classification accuracy of 83 percent at 0 dB SNR under mix of Gaussian and Impulsive noise conditions. We have also observed that when we use more symbol number for classification, we have better results.

We will investigate how the performance of AMC in frequency selective channels can be improved in our further studies.

REFERENCES


Abstract— Partial Transmit Sequence (PTS) scheme is an effective peak-to-average power ratio (PAPR) lessening tool for Orthogonal Frequency Division Multiplexing (OFDM) system. However, computational complexity for the optimum phase factors searches of PTS scheme entails huge computational requirements and limits its applicability to practical applications especially for high-speed data transmissions. This study proposes a PAPR reduction method with a low computational complexity based on a combination of Cuckoo search optimization algorithm with PTS scheme in OFDM system. In terms of PAPR and computational complexity reductions, the performance of the Cuckoo-PTS scheme is comparatively investigated by performing a set of simulations with different PTS schemes.

Keywords— PAPR, OFDM, partial transmit sequence (PTS), Cuckoo search, phase factor

I. INTRODUCTION

Over the past few decades, due to key features as, high bandwidth efficiency, narrowband interference, efficient implementation and robustness to frequency selective fading [1–2], orthogonal frequency division multiplexing (OFDM) systems have received increasing attention and become one of the promising techniques for high data rate transmissions in digital communication. However, OFDM systems are susceptible to high peak-to-average power ratio (PAPR) [5] which causes significant reductions in radio frequency power amplifiers and yields high complexity in digital-to-analog and analog-to-digital converters. High PAPR also leads to implementation problems for the systems with large numbers of subcarriers. The PAPR can be reduced with the applications of constitutional arrangements and restrictions which in turn adversely affect the operation of the power amplifier and the spectral efficiency of OFDM systems.

Numerous methods with different advantages and drawbacks have been appeared in the literature for the reduction of PAPR in OFDM systems such as selected mapping [4], clipping and filtering [5], clipping [6], partial transmit sequence (PTS) [7-8], coding [9], tone injection [10], tone reservation [11], peak windowing [12], interleaving [13] and active constellation extension [14] have been appeared. Among these methods, the PTS is one of the popular distortionless techniques and provides remarkable PAPR reduction performance. However, the search and combination of phase factors which requires an exhaustive search procedure is the major drawback of PTS technique. The replacement of optimum phase factor search steps of PTS scheme with a suboptimal search technique offers reduction in computational complexity of PTS scheme. Many suboptimal PTS schemes, including the harmony search (HS) [15], parallel tabu search (parallel-TS) [16], artificial bee colony (ABC) [17], differential evolution (DE) [18], particle swarm optimization (PSO) [19] and random search [20], have been presented in the literature and it is reported that PAPR reductions with low computational complexities are successfully obtained.

In this paper, a suboptimal PTS scheme based on Cuckoo Search Optimization Algorithm is proposed for the PAPR reduction in OFDM systems. The Cuckoo Search Optimization Algorithm, proposed by Xin-she Yang and Suash Deb, is a relatively new optimization method that mimics the breeding behavior of some cuckoo species.

II. MODEL OF OFDM SYSTEM BASED ON PTS SCHEME

The OFDM system model based on PTS scheme is given in Fig. 1. First, the incoming bit sequences are interleaved to transform burst errors into random errors. The interleaved signal is modulated with 16-QAM modulation. To recover the original signal at the receiver, side information is transferred. The signal is passed through a high power amplifier and then a cycle prefix (CP) is applied to the signal to combat with intersymbol interference (ISI) induced by communication channel. The CP is removed from the signal at the receiver. The phase of original signal is acquired with the use of phase rotation and side information following the realization of fast Fourier transform (FFT). After 16-QAM demodulation, each demodulated symbol is conveyed to the original place in the bit sequence by means of the deinterleaver [1].
values are as follows:

\[ \text{alternative} \]

rotation \[ \text{represented} \]

signal \[ \text{subblocks} \]

carriers with equal size, \( N \), such that \( v \) multiplication of subblocks with optimized phase rotation distortionless PAPR reduction algorithm based on

The block diagram of a typical partial transmit sequence is shown in Fig. 2.

III. CONVENTIONAL PTS

Partial Transmit Sequence (PTS) is a promising distortionless PAPR reduction algorithm based on multiplication of subblocks with optimized phase rotation vectors. In a typical PTS scheme, the input signal is partitioned into \( M \) disjoint subblocks each of which have a set of subcarriers with equal size, \( N \), such that

\[ X = \sum_{m=0}^{M-1} X^{(m)} \quad (11) \]

Oversampling is implemented to subblocks by padding \( L(N - 1) \) zeros to original OFDM blocks. Oversampled subblocks are transformed into time domain and mathematically expressed by

\[ x = \text{IFFT} \left( \sum_{m=0}^{M-1} X^{(m)} \right) = \sum_{m=0}^{M-1} x^{(m)} \]

The goal of PTS scheme is to obtain a combination of \( x \) signal with a rotational phase vector \( b = [b_1 \ b_2 \ \ldots \ b_{M-1}]^T \) to offer the lowest PAPR that is represented by

\[ \bar{x} = \sum_{m=0}^{M-1} b_m x^{(m)} \]

The individuals of rotational phase vector is \( b_m = e^{i \theta_m} \), where \( \theta_m \) is selected freely between 0 and \( 2\pi \). The allowed rotational phase vector combinations is \( W^N \), where \( W \) is the number of allowed phase factor. However, the phase factor for the first subblocks is taken as \( b_0 = 1 \), then there are \( W^{M-1} \) alternative rotational phase vector combinations. The \( b_m \) values are as follows:

\[ b_m = \pm 1 \quad \text{for} \quad W = 2 \]

The block diagram of a typical partial transmit sequence is shown in Fig. 2.

IV. CUCKOO SEARCH OPTIMIZATION ALGORITHM

The Cuckoo Search (CS) Algorithm, proposed by Yang and Deb [ 7 ], is a recently developed promising optimization algorithm that utilizes the offensive reproduction tactics of the cuckoo bird. The CS algorithm is built on the following basic assumptions: each cuckoo can lay only one egg in a randomly chosen nest at a time, high-quality eggs in best nests can receive more chances to survive in next generation, the number of convenient host nests is limited and possibility of discovering cuckoo egg is defined in a range between 0 and 1. In the case of cuckoo egg detection, the host bird can either abandon the nest or throw out the cuckoo egg. The cuckoo eggs in CS algorithm represent the potential solutions.

The replacement of a host bird egg (not so good solution) with a cuckoo egg (better solution) is the goal of the CS algorithm. The assumption of each nest has only one cuckoo egg provides no distinction between egg, nest and cuckoo, and makes the application of CS algorithm simpler. The CS algorithm starts with the generation of initial population of nests with the size \( n \). In this initial population, nests are randomly distributed over the search space and randomly selected design variables are bounded by the lower and upper boundaries in the search space.

A new solution, \( x_i^{(t+1)} \), for the \( i^{th} \) cuckoo is generated using Levy flight according to the following law:

\[ x_i^{(t+1)} = x_i^t + \alpha \Theta \text{Levy}(\lambda) \]

where \( \alpha \) is the step size and is defined with respect to scale of the problem of interests. The step size must be greater than 0, and in most cases, can be unity or some other constant. Levy Flight is a random walk in which Levy distribution determines the random step size.

\[ \text{Levy} \sim u = \tau^{-\lambda}, 1 < \lambda \leq 3 \]

V. SIMULATIONS

The randomly generated OFDM signals with \( N = 256 \) subcarriers with 16 – QAM modulation were used in computer simulations. The number of the population, \( NP \), number of the
generation, number of sub-blocks, $M$, and the number of the phase factor, $W$, was selected as 20, 50, 16, 4 respectively. The complementary cumulative density functions (CCDFs) of the PAPR were obtained with the use of 10000 random OFDM symbol generations. The solid state power amplifier (SSPA) with input back-off factor, $IBO = 9 \text{ dB}$, and smoothness factor, $p = 2$ was used as an amplifier. The additive white Gaussian noise (AWGN) channel was chosen as communication channel. The simulation parameters were summarized in the Table 1.

Figure 3 illustrates the CCDFs of PAPR of PTS scheme based on cuckoo search optimization algorithm (CS), random search (RS) and optimum PTS. The PAPR values of the OFDM system are 10.96 dB for original, 7.62 dB for random search algorithm, 7.45 dB for PSO algorithm, 6.8 dB for cuckoo search algorithm, 6.37 dB for Optimum algorithm, at $CCDF = 10^{-3}$. It is seen that random search yields the worst performance while cuckoo search optimization algorithm yields the best performance for the PAPR reduction of OFDM system.

Table 1. Parameters for Simulations

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Quantity</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>QAM</td>
<td>modulation method</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>number of sub-carriers</td>
<td>256</td>
</tr>
<tr>
<td>M</td>
<td>number of sub-blocks</td>
<td>16</td>
</tr>
<tr>
<td>W</td>
<td>number of phase factor</td>
<td>4 ($\pm 15$)</td>
</tr>
<tr>
<td>SSPA</td>
<td>linear amplifier</td>
<td></td>
</tr>
<tr>
<td>IBO</td>
<td>input back-off</td>
<td>9 dB</td>
</tr>
<tr>
<td>P</td>
<td>smoothness factor</td>
<td>2</td>
</tr>
<tr>
<td>AWGN</td>
<td>channel</td>
<td></td>
</tr>
<tr>
<td>NP</td>
<td>number of the population</td>
<td>20</td>
</tr>
<tr>
<td>NG</td>
<td>number of the generation</td>
<td>50</td>
</tr>
</tbody>
</table>

Figure 4. Comparison of the PAPR0 (dB) versus CCDF for CS-PTS with different values $G$ for $W = 4$, $M = 16$, $NP = 20$, and $G = 50$.

According to Figure 5, the PAPR is $7.28 \text{ dB}$, $7.04 \text{ dB}$, $6.93 \text{ dB}$ and $6.81 \text{ dB}$ at $CCDF = 10^{-3}$ for $P = 25$, $P = 50$, $P = 75$ and $P = 100$, respectively. It is observed that an increment in population yields an increase in PAPR reduction performance.

Figure 5. Comparison of the PAPR0 (dB) versus CCDF for CS-PTS with different values $G$ for $W = 4$, $M = 16$, $NP = 20$, and $NG = 25$.

VI. CONCLUSION

In this paper, PTS based on cuckoo search optimization algorithm in OFDM system is proposed for the PAPR reduction with less computational load. In order to evaluate the PAPR reduction performance of the proposed CS-PTS scheme, the CCDF simulations are performed. Also, its performance is compared with the performances of original PTS, O-PTS, PSO-PTS and RS-PTS in the OFDM systems. Simulation results show that the PAPR reduction performance of the CS-PTS in the OFDM system is better than that of O-PTS, PSO-PTS and RS-PTS in the OFDM system.
REFERENCES


Wi-Fi Control of Mobile Robot Motion Types Based on Differential Drive Kinematics Modelling Approach

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Abstract—Recently, utilization of mobile robots has increased substantially. Accordingly, wireless communication is preferred in mobile robots. QBot 2 is an autonomous ground robot which is a new product of Quarc. The QBot 2 utilizes an onboard data acquisition card and a wireless embedded computer to measure the onboard sensors and drive motors. In this study, QBot 2 mobile robot is evaluated in terms of its ability to maneuver. In this way, controlling QBot 2 mobile robot in real time is planned while a command recognition system is developed. Connection with the QBot 2 is carried out in a wireless environment. A Simulink model is developed in MATLAB® environment. The created model is built with Quarc control software. Compiled model is downloaded with TCP/IP connection to QBot 2 and the application is carried out on an embedded computer. The QBot 2 mobile platform consists of two central drive wheels mounted on a common axis. This drive configuration is known as differential drive. The two drive wheels are independently driven forward and backward in order to actuate the robot. Motion of the wheels is realized using high performance DC motors. When the results are analyzed, 13 different motion types are observed in total. The observed motion types could be used as references in future works since many practical applications, such as the remote control of QBot 2 mobile robot via the human voice, require the availability of different motion types.

Keywords—Intelligent robotic systems, Mobile robots; Wi-Fi based remote control.

I. INTRODUCTION

The first major mobile robot development effort was Shakey, developed in the late 1960s [1]. Recently, utilization of mobile robots has increased substantially. Mobile robot systems are designed for research, education, commercial, industrial, space missions or different purpose. Today researchers are focusing on mobile robots owing to their potential applications in hazardous environments [2], household tasks [3], in the field of agriculture [4], medical [5], and military applications [6-7].

The basic technologies involved in these applications are a suitable robotics platform equipped with enhanced sensors and a software framework for fast validation of concepts. The existing robotic platforms are presented for different applications [8-9]. The significance of developed software algorithms on computers is the increase in robotic control. Quanser has developed Quarc real time control software for MATLAB® Simulink [10].

The QBot 2 is ideally suited for research applications such as differential drive kinematics, forward and inverse kinematics, dead reckoning and odometric localization, path planning and obstacle avoidance, 2D mapping and occupancy grid map, image acquisition, processing and reasoning, simultaneous localization and mapping (SLAM), high level control architecture of mobile robots and, vision-guided vehicle control. Applications of QBot which is previous generation of Quanser ground robots are mentioned in the literature [11-13].

The QBot 2 mobile platform consists of two central drive wheels mounted on a common axis that bisects the robot. The two drive wheels are independently driven forward and backward in order to actuate the robot [14]. This drive configuration is known as differential drive [15]. There are different applications of wheeled mobile robots [16].

In this study, QBot 2 mobile robot is evaluated to explore its ability to maneuver. In this way, controlling QBot 2 mobile robot in real time is planned while a command recognition system is developed.

Interacting with mobile robots using speech is of particular interest to researchers since verbal communication is the most natural way of communication for human beings. Speech has been previously used to perform different tasks, such as command based voice teleoperation of a mobile robot [17-18].

The paper is organized as follows. Section II. introduces how to be teleoperated mobil robot QBot 2. Then, differential drive kinematics is described in Section III. The simulation results and analysis are described in details in Section IV. Finally, Section V. concludes the paper.
II. THE TELEOPERATED MOBILE ROBOT QBot 2

The QBot 2 utilizes an onboard data acquisition card and a wireless embedded computer to measure the onboard sensor and drive motors. Connection with the QBot 2 is carried out in a wireless environment A Simulink model is developed in MATLAB® environment. The created model is built with Quarc control software. Compiled model is downloaded with TCP/IP connection to QBot 2 and the application is carried out on an embedded computer.

A. The Hardware Platform

The QBot 2 is an autonomous ground robot which is a new product of Quanser. The QBot 2 is comprised of a Yujin Robot Kobuki platform, a Microsoft Kinect RGB camera and depth sensor and a, data acquisition card (DAQ) with a wireless embedded computer. The embedded computer system mounted on the mobile robot uses the Gumstix DuoVero [19] to run QUARC and interface with the QBot 2 data acquisition card [20].

B. Establishing Wireless Connection

Between the host computer and the QBot 2 connection can be either wired or wireless communications. In this study, the QBot 2 communicates with the host computer by utilizing an ad-hoc peer-to-peer wireless TCP/IP connection. The network established is called GSAH. The teleoperated mobile robot QBot 2 is shown in Fig.1.

Fig. 1. The Teleoperated mobile robot Q Bot 2

QBot 2 can be combined with other QBot units, QBall 2 and QBall-X4 unmanned aerial vehicles, or third-party autonomous vehicles, and an open-architecture, multi-purpose, multi-agent platform can be built for research [21].

C. Software Framework

Quarc 2.5 must be installed on host computer [10]. Quanser real time control software is a rapid control software to run simulink generated code under Windows. Quarc also provides for users with the ability to arrange the control parameters while the model is running.

D. Control of Software Blokset

The QBot 2 is accessible through different block sets in MATLAB® Simulink. “The Hardware in the Loop (HIL) Initialize” block set is utilized to configure the drivers and hardware interface for the QBot 2. “HIL Read/Write” block set is utilized to read from sensors and/or write to outputs. “Kinect Initialize” block set is used to initialize the Kinect sensor. “Kinect Get Image and Depth Sensor” blocks are used captures RGB and depth data from the Kinect sensor. Display Image” block set is used to transmit the input data (RGB or depth) from QBot 2 to the PC and displays them on the monitor. Other than these blocks, the “Host Initialize” block can be used to make use of external input devices such as a keyboard or joystick.

III. TWO WHEELED DIFFERENTIAL ROBOT MODEL

The QBot 2 mobile platform consists of two central drive wheels mounted on a common axis. The two drive wheels are independently driven forward and backward in order to actuate the robot. Motion of the wheels is realized using high performance DC motors. This drive configuration is known as differential drive [22-23]. Modeling of the QBot 2 is shown in Fig. 2 (a) and top view of the QBot 2 is shown in Fig. 2 (b).

Fig. 2. Left: Illustration of the QBot 2; Right: The QBot 2—top view

When there exist differences between velocities of two driving wheels, the robot must rotate around a point that lies along the common left and right wheel axis. The point that robot rotates about is known as the ICC (Instantaneous Center of Curvature). The trajectory of robot can be controlled by changing the velocities of two driving wheels. The wheel angular speed be denoted \( \omega \), \( R \) be the signed distance from to the ICC to the midpoint between the left and right wheels to the ICC, \( L \) be the distance between the left and right wheels, \( \theta \) be the heading angle of the robot, and \( V_c \) be the (forward/backward) speed of the robot chassis center. The motion of the QBot 2 velocity of the wheels can be summarized in the following equations:

\[
V_R = \omega \left( R + \frac{L}{2} \right) \\
V_L = \omega \left( R - \frac{L}{2} \right)
\]  

Equation 1 and 2 can be solved at any instance of time for \( \dot{V}_c, \dot{\omega}, R \) as follows;
\[ V_c = \frac{(V_R + V_L)}{2} \]  
\[ \omega = \frac{d\theta}{dt} = \frac{(V_R - V_L)}{L} \]  
\[ R = \frac{L(V_R + V_L)}{2(V_R - V_L)} \]  

IV. THE SIMULATION RESULTS AND ANALYSIS

In this study, QBot 2 mobile robot is evaluated to explore its ability to maneuver. For this reason a Simulink model is developed, shown in Fig. 3. In this model, we can command left and right wheel speeds of the QBot 2. When both wheels speeds are set, as shown in Fig. 3 (A), we observe linear and angular velocities, as shown in Fig. 3 (C). We analyzed that the measured and the calculated wheel speeds are different from each other, as shown in Fig. 3 (B). The difference between the calculated velocities and the measured ones as a result of measurement error are caused by load, friction and disturbances to the wheels. This concept is known as Forward Kinematics in the literature [22]. Forward Kinematics is used to determine the linear and angular velocity of the robot in the real space coordinate frame given robot’s wheel speeds.

![Fig. 3. Snapshot of the Simulink Block Diagram](image)

When \(-A, -B, 0, B, A\) speed values are set to the left and right wheels in accordance with the equality \(0 \leq B \leq A \leq 0.65 \text{ m/s}\), 13 different motion types are observed in total. Observed maneuvers information of the QBot 2 is presented in Table I. When both wheels rotate at the same speed, we observe linear motion in a straight line as, shown in the first two rows in Table I. When both wheels rotate at the same speed but in the opposite direction, we observe rotation about the midpoint of the wheel axis and rotate in place, as shown in the third and fourth rows in Table I. When only one wheel speed of the QBot 2 is set, we observe rotation around the non-moving wheel as shown in the fifth, sixth, ninth and tenth rows in Table I. When a wheels turns faster than the other, QBot 2 turns in an arc towards the slower wheel as shown in the seventh, eighth, eleventh and twelfth rows in Table I. When \(\omega\) has a positive value \((\omega > 0)\), it creates a counter clockwise rotation (CCW) whereas a negative \(\omega\) value a clockwise rotation (CW). If \(R\) has a negative value, the linear and angular velocities should have different signs. Specially, If the QBot 2 is moving forward \((V_c > 0)\), it should be rotating clockwise \((\omega < 0)\), and if it is moving backwards \((V_c < 0)\), it should be rotating counter clockwise \((\omega > 0)\).

<table>
<thead>
<tr>
<th>INPUT VALUES OF SYSTEM</th>
<th>OUTPUT VALUES OF SYSTEM</th>
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<th>POSITION</th>
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<td>(V_L)</td>
<td>(V_C)</td>
<td>(\omega_C)</td>
</tr>
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<td>(A)</td>
<td>(A)</td>
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<td>(-)</td>
<td>0</td>
</tr>
<tr>
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<td>(-A)</td>
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<td>(A)</td>
<td>0</td>
<td>CW</td>
</tr>
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<td>(0)</td>
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<td>CW</td>
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<td>CW</td>
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<tr>
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<td>(A)</td>
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</table>
V. CONCLUSION

In this study, QBot 2 mobile robot maneuvers were analyzed. Determined left and right wheel speed values are entered with a model created in MATLAB Simulink using QUARC control software. When the results are analyzed, 13 different motion types are observed in total.

The difference between the calculated velocities and the measured ones as a result of measurement error are caused by load, friction and disturbances to the wheels.

The observed motion types could be used as references in future works since many practical applications, such as the remote control of QBot 2 mobile robot via the human voice, require the availability of different motion types.

REFERENCES

The Effect of Viewing Angle on Detection of Landmines from Thermal Time Series Images Using Active Thermography

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Abstract—Use of landmines in soils is a significant international threat facing the world today. There are no safe and highly reliable methods or inspection systems capable of detecting landmines in all situations. The use of infrared thermography is one of the promising methods for mine detection tasks. In infrared thermography, the investigation is done in either way: actively or passively. In this study, thermal signatures of the active infrared time difference images of buried mines and sand are investigated for different camera angles. It is aimed to find the effects of shot angles of the thermal camera on the performance of landmine detection. The experiments are performed at a sandbox emplaced in an indoor laboratory environment. A metal and a plastic antipersonnel mine are buried at 2 cm depth in sandbox. The sand surface is initially heated homogeneously by an infrared heater (2400 W) for 10 minutes on different days. During the cooling phase of the surface, a sequence of images are captured with an LWIR (8-12 µm band) camera (FLIR T 650 SC), which is 280 cm away from the detection area at different angles (90°, 60° and -60°). Images of the size of 480×640 pixels are taken at 15 seconds intervals during one hour. “Thermal signatures” of the buried mines and soil in three viewing angles are compared in MATLAB® environment. The results show that the locations of landmines are easily detected from the captured images during the cooling phase of the surface since observable differences develop between temperature signatures of landmines and sand, but the observation angle of camera has little affects on the detection performance. In addition, it is found that one hour measurement period is accurate for the detection of landmines at 2 cm depth in active thermography.

Keywords—Landmine detection; Thermal infrared imagery; Active thermography.

I. INTRODUCTION

Infrared (IR) thermal imaging, also often briefly called thermography, is a very rapidly evolving field in science as well as industry owing to the enormous progress made in the last two decades in micro system technologies of IR detector design, electronics, and computer science. Thermography nowadays is applied in research and development as well as in a variety of different fields in industry such as nondestructive testing, condition monitoring, and predictive maintenance, reducing energy costs of processes and buildings, detection of gaseous species, and many more [1]. IR thermal imaging has also been widely used for landmine detection.

The detection of landmines and clearance is still a time consuming and unsafe task. Additionally, efficient and accurate detection of buried mines is still a challenging problem [2].

There is no universal technique capable of detecting landmines in all conditions. Infrared thermography is a promising technique in the detection and discrimination of the landmines. The detection principle is based on the variation of the ground temperature due to the presence of buried or surface landmines.

Sand and mines have different thermal properties and this difference can be observed on the surface through the thermal sensors. Since thermal property is a dynamic behavior driven by radiation from the external heating system, it can change with the temperature in a few minutes and it can be observed better in thermal image time series than a single image.

Active thermography technique can be applied to enhance the contrast between the possible targets and the background. This contrast stems from the difference in radiant characteristics between the landmines and the background soil.

Emissivity value, which is one of these characteristics, plays a significant role in the determination of correct temperature of an object surface [3]. The source of uncertainty in temperature measurement with the infrared camera can be listed as followings: emissivity (ε) of objects, infrared detector-to-surface angle and distance. Those are mainstream technical factors for an accurate infrared thermographic measurement.
Some authors [4] [5] [6] have used analytical, numerical and experimental methods to model the thermal signatures of land mines. But, in our humble opinion, how angle of observation influences the results has not been investigated in detail yet.

Therefore, the main objective of this paper is to evaluate the effect of change in camera angle on detection performance of buried landmines.

II. BACKGROUND

A. Mine Problem

Landmines are explosive devices hidden just below the surface designed to be detonated by contact of people or vehicles, as they pass over or near them. Still some 60 countries around the world are contaminated by landmines and thousands of people continue living with a risk of losing their life or limb. In addition, emplaced landmines hinder the cultivation of large productive areas. Besides, they maintain a sense of insecurity long after conflicts end, delay peace processes and impede countries’ development for years [7].

Because of these horrendous effects, a lot of research and technological developments are needed to solve the detection and clearing of landmines problem. One widely searched solution for this problem is IR thermal imaging.

B. Thermal imaging

Each material shows a characteristic thermal response to a given stimulus, also known as the thermal signature. Thus, the cooling or heating process affects buried objects and the surrounding soil in a different way. This difference is due to the fact that the mines are better insulators than the soil. The general concept of using infrared thermography for mine detection is based on the fact that mines may have different thermal properties from the surrounding material [8]. Thermal imaging devices measure the emissivity of surfaces in an area at various temperature ranges.

Uniquely, IR can work in either way, actively or passively. It can work by accepting only the natural radiation from the object called as passive thermography, or it can provide an extra heat source and receive the artificial radiation created by that heat source dubbed as active thermography [9].

Most thermal detection concepts involve single snapshot of the region of interest. The soil over a mine has different thermal dynamics than homogeneous soil and, as a result, a time sequence of images can often produce better detection than a single image [10].

Consequently, the soil temperature on the ground above the mines is often different from that of the background. This temperature can be measured by an IR imaging system placed above the soil area.

III. EXPERIMENTS

The equipment required for the experiments consists of model anti-personal landmines (plastic and metal), thermal camera, a tripod of camera stand or framework, sandbox and a heating unit.

The landmines can be categorized mainly into two sections according to their materials, metal or plastic mines. The surrogate model mine used in the experimental study is Plastic DM-11 (partly filled with wax whose thermal properties are similar to TNT) and Metal M-16 anti-personnel mines (APM’s) as shown in Fig. 1. DM-11 has a diameter of 0.08 m and a height of 0.035 m. M-16 has a diameter of 0.12 m and a height of 0.20 m.

The mines were buried in a sandbox which has a height of 1.85 m length, a width of 1.55 m and a depth of 0.225 m, filled with sand. The thermographic imaging was performed with a portable infrared camera (FLIR T 650 SC) equipped with an uncooled micro bolometer, a focal plane array infrared detector with a spectral range between 7.5 – 13.0 μm and 480×640 pixels.

The camera was attached to a framework, consisting of a fixed attachment point for the camera. The sandbox was located at the base of the framework and the camera was focused on the center of the sandbox.

Fig. 1. Experimental setup for an assessment of angular variation of emissivity. The FLIR T 650 SC was rotated about the sample and fixed at 30-degree intervals. Plastic APM DM 11 (up) and Metal APM M 16 (down) Positions.

Infrared Heater (UFO-L2300-2400 Watt Power) was used as a heat source. The heating phase (active thermography) is shown in Fig. 2.
All measurements were performed for 1 day for each angle. Images were analyzed with commercially MATLAB and FLIR IR Research Software.

IV. RESULTS

Three types of experiments performed at the viewing angles of 90°, 60° and -60° as it is shown in Fig.3 during three days. The acquired thermal images are stored in a personal computer. The model mines were buried into a depth of 0.02 m beneath the sand surface.

The sand surface was initially heated by an infrared heater (2400 W) for 10 minutes in each day. During the cooling phase of the surface, a sequence of images was captured with FLIR T-650 SC camera placed in 280 cm distance from the detection area. Images of the size of 480×640 pixels were taken at 15 seconds intervals during one hour.

The temperature effect of the presence of the mine on the sand surface at each angles are clearly shown in Fig. 4 (a, b, and c).

As it is shown in Fig.4, the surface temperature of the sand above plastic mine was higher than the surface temperature of the sand beside mine. However, the situation was just opposite when it comes to metallic mine. The hot and cold surface spots caused by the energy reflected from the surface over mines generally became apparent within a similar time frame [4].

The results showed that the amplitude of the surface temperature change above the mine was much greater than that on the surface beside it; this was caused by the heating method. In all tests, the locations of the mines were identified using FLIR T-650 SC thermal camera and Research IR Program. The evolution of the “hot spot” and “cold spot” above the mines can be observed from the results shown in Fig. 4.
Our experiments confirmed that emissivity nearly remains constant from 60° to -60° degrees from the horizontal. These results were in agreement with what reported in the textbook of Infrared Thermal Imaging Fundamentals, Research and Applications [1], which explains the influence of viewing angle on emissivity of a surface.

Angular dependency of emissivity (angle of observation) that has an influence on images was recorded with an IR camera system. However, Figure 5 demonstrates an effect that fortunately holds for nearly all practically important surfaces: the emissivity is nearly constant from the normal direction 0° to at least 40 or 45° [1].

![Fig. 5. The emissivity values at different angles [1].](image)

The study was carried out to understand how the viewing angle was influenced to the emissivity. Changing in the emissivity was recorded in each direction, and the results are shown in Fig. 6 (a, b, and c). The difference between the two temperature signature profiles (sand and mines) was plotted in MATLAB for each test.

![Fig. 6. Thermal signatures of a minefield; images taken at (a) 90°, (b) 60° and (c) -60°.](image)

V. CONCLUSION

In our study the effect of viewing angle is investigated by combining the analysis of temporal IR image sequences, showing the dynamic scene behavior during time variant heating by an infrared heater. The results show that different viewing angles (for 90°, 60° and -60°) have relatively little effect on the temperature at the surface. The emissivity is approximately constant at the viewing angles between 60° and -60°.

Experiments have shown that active thermography has strong positive effect on thermal signature in a short time. It can be especially useful in military tasks.

The thermal properties of the mine itself can play a significant role according to the thermal signatures. Also, it is shown that 60 minutes duration is enough to produce thermal signatures for buried mines at a depth of 2cm from the surface with active thermography.
VI. REFERENCES


MORTAR MIXING AUTOMATION SYSTEM
USING PLC BASED SCADA (ICAT)

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Abstract—With the rapid development of industrial technology, industrial automation systems will provide safe, quality, fast and competitive product manufacturing. Programmable Logic Controller (PLC) is preferred in industrial automation systems due to its features such as process speed, quality and reliability, small physical size and easy installation. As PLC systems develop, SCADA systems are began to use in a wide area. Industrial plants can be monitored remotely can be controlled by time and past data can be stored using SCADA systems with PLC.

In this study, prototype and implementation of SCADA based mortar mixing automation system with PLC was carried out. The system was controlled by S7-200 PLC and WinTr SCADA interface. All parameters can be entered, monitored and controlled by means of SCADA interface. In the system, mortar mixture were comprised of cement, aggregate, gravel and water. Each material was located in separate hoppers. When material values for mixture were entered, hoppers cover was opened respectively. The amount of entered value and weighed value were compared and when their values were equal, hopper covers were closed thanks to loadcells located at the bottom of the hoppers. Materials were transferred to mixing hopper by means of band system after sand, aggregate and gravel were added. Then, water was pumped from the water hopper to the mixing hopper and all materials were mixed by mixer.

Keywords—PLC, SCADA, mortar mixing automation

I. INTRODUCTION

Industrial automation systems will provide qualified, safe, fast and competitive way for product manufacturing with the rapid development of industrial technology. With the use of automation systems, production desired and planned in plants can be made and also systems can be monitored remotely. Furthermore, automation technology also provides fast and reliable production [1].

Mortar mixed systems work under the control software because they are completely subject to the automation system. Nowadays, Programmable Logic Controller (PLC) is used in almost every area of the industry but it is used especially in automation systems. PLC has a wide range of application in all areas of industry such as air conditioning, elevator, ventilation, cooling, packaging, storage and transportation plants, automobile industry, petroleum filling and washing plants, cement industry, lighting plants, all kinds of machines, electropneumatic and hydraulic systems [2].

SCADA systems are used in wide area as long as PLC systems evolve. They enable to remote communication. Thus, they provide easier intervention to long distance system. Nowadays, SCADA systems are widely used in various fields such as energy, water, gas, cement, climatization, transportation, security and banking [3]. Usage of PLC and SCADA systems has many advantages. For example, quality increases, process monitoring is easier, failure caused by human factor and occupational accidents can be minimized [4].

In this study, prototype and application of mortar mixing automation system which is based on PLC and SCADA was realized. The system was controlled by the S7-200 PLC and WinTr SCADA interface. PLC and SCADA interface has worked simultaneously. Thus, system can be monitored and controlled in real time.

II. PROTOTYPE DESIGN OF SYSTEM

A. PLC Properties used in the System

In this study, Siemens S7-200 CPU 224 was used as PLC. S7-200 includes a compact microprocessor to create a powerful Micro PLC, integrated power supply, input and output circuits. CPU 224 model has 14 inputs and 10 outputs [5, 6]. The block diagram of system is shown in Figure 1.

![Block diagram of system](image)

B. Design of System

Prototype of the mortar mixing automation system is shown in Figure 2 and prototype material list is shown in Table 1.

---

Table 1: Prototype Material List

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>50 kg</td>
</tr>
<tr>
<td>Aggregate</td>
<td>70 kg</td>
</tr>
<tr>
<td>Gravel</td>
<td>30 kg</td>
</tr>
<tr>
<td>Water</td>
<td>20 liters</td>
</tr>
<tr>
<td>Mixing Motor</td>
<td>1 piece</td>
</tr>
<tr>
<td>Belt Motor</td>
<td>2 pieces</td>
</tr>
<tr>
<td>Hopper Cover On/Off Motors</td>
<td>3 sets</td>
</tr>
<tr>
<td>Load Cells</td>
<td>4 units</td>
</tr>
</tbody>
</table>

---
In the system, mortar mixture were comprised of cement, aggregate, gravel and water. Each material located in separate hoppers. Loadcells were located under each hopper. Loadcell is an analogue sensor and its output voltage is between 0-3.6 mV. However, analogue values can’t be read directly by the PLC which can only detect logic signals. Therefore, an EM-235 analogue module is needed to convert analogue value to digital value. Information coming from loadcells was converted digital value in accordance with PLC. EM-235 module has three inputs in the system and they are shown in Table II. The output value of the EM-235 module is between 0-10 V [5]. However, output voltage of loadcells is lower than the output voltage of the analogue modules and it needs to be amplified. Therefore, an amplifier circuit was designed for this and shown in Figure 3.

### TABLE I
**Prototype Material List**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water pump</td>
</tr>
<tr>
<td>2</td>
<td>Gravel hopper</td>
</tr>
<tr>
<td>3</td>
<td>Aggregate hopper</td>
</tr>
<tr>
<td>4</td>
<td>Cement hopper</td>
</tr>
<tr>
<td>5</td>
<td>First Loadcell</td>
</tr>
<tr>
<td>6</td>
<td>Second Loadcell</td>
</tr>
<tr>
<td>7</td>
<td>Third Loadcell</td>
</tr>
<tr>
<td>8</td>
<td>Belt motor</td>
</tr>
<tr>
<td>9</td>
<td>Conveyor hopper</td>
</tr>
<tr>
<td>10</td>
<td>First inductive sensor</td>
</tr>
<tr>
<td>11</td>
<td>Second inductive sensor</td>
</tr>
<tr>
<td>12</td>
<td>Third inductive sensor</td>
</tr>
<tr>
<td>13</td>
<td>Mixer</td>
</tr>
<tr>
<td>14</td>
<td>SCADA interface</td>
</tr>
<tr>
<td>15</td>
<td>Fuses</td>
</tr>
<tr>
<td>16</td>
<td>S-7 200 CPU 224 PLC</td>
</tr>
<tr>
<td>17</td>
<td>EM-235 Analog Module</td>
</tr>
<tr>
<td>18</td>
<td>Relay circuit</td>
</tr>
<tr>
<td>19</td>
<td>Amplifier circuit</td>
</tr>
<tr>
<td>20</td>
<td>Connectors</td>
</tr>
</tbody>
</table>

In the system, mortar mixture were comprised of cement, aggregate, gravel and water. Each material located in separate hoppers. Loadcells were located under each hopper. Loadcell is an analogue sensor and its output voltage is between 0-3.6 mV. However, analogue values can’t be read directly by the PLC which can only detect logic signals. Therefore, an EM-235 analogue module is needed to convert analogue value to digital value. Information coming from loadcells was converted digital value in accordance with PLC. EM-235 module has three inputs in the system and they are shown in Table II. The output value of the EM-235 module is between 0-10 V [5]. However, output voltage of loadcells is lower than the output voltage of the analogue modules and it needs to be amplified. Therefore, an amplifier circuit was designed for this and shown in Figure 3.

### TABLE II
**Addresses of the Input Terminal of the EM-235 Module**

<table>
<thead>
<tr>
<th></th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIW0</td>
<td>Analogue value reading of first weighing.</td>
</tr>
<tr>
<td>AIW2</td>
<td>Analogue value reading of second weighing.</td>
</tr>
<tr>
<td>AIW4</td>
<td>Analogue value reading of third weighing.</td>
</tr>
</tbody>
</table>

Six DC motor was used in order to open and close the hopper covers. Three DC motor provided to open the hopper covers and the other three motor provided to close the hopper covers. Materials for the mixture collected respectively in the conveyor hopper located on the belt system and it was transferred to the mixing hopper. The movement of the belt system was provided with inductive sensors located on belt system.

### C. SCADA Interface

In this study, SCADA interface was designed by using WinTr SCADA software. SCADA interface is shown in Figure 4.

PLC and SCADA interface work synchronously, so system can be controlled from interface in an instant. There are hoppers for the materials used in mortar mixing. When material values for mixture are entered from the interface, hopper covers are opened respectively. Information which comes from loadcells is transferred to PLC via analogue module. When entered value equals to weighed value, hopper covers are closed. Materials are transferred respectively to the conveyor hopper which is on the belt system. Materials in conveyor hopper are transferred to the mixing hopper after all materials are added. Then, water is pumped into the mixing hopper and all materials are mixed by means of mixer.
D. Flowchart of the Program

The flowchart of the program is shown in Figure 5.

![Flowchart of the Program](image)

Figure 5. Flowchart of the program

E. Expression of the Program with Ladder Diagram

Addresses of the input and output terminal of the PLC are shown in Table III.

<table>
<thead>
<tr>
<th>Input</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>I0.0</td>
<td>Second hopper stop sensor</td>
</tr>
<tr>
<td>I0.1</td>
<td>First hopper stop sensor</td>
</tr>
<tr>
<td>I0.2</td>
<td>Third hopper stop sensor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Output</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q0.0</td>
<td>First hopper pump (On / Off)</td>
</tr>
<tr>
<td>Q0.1</td>
<td>First weighing hopper pump (On/ Off)</td>
</tr>
<tr>
<td>Q0.2</td>
<td>Second hopper pump (On / Off)</td>
</tr>
<tr>
<td>Q0.3</td>
<td>Second weighing hopper pump (On/ Off)</td>
</tr>
<tr>
<td>Q0.4</td>
<td>Third hopper pump (On / Off)</td>
</tr>
<tr>
<td>Q0.5</td>
<td>Third weighing hopper pump (On/ Off)</td>
</tr>
<tr>
<td>Q0.6</td>
<td>Water Pump</td>
</tr>
<tr>
<td>Q0.7</td>
<td>Belt Motor</td>
</tr>
<tr>
<td>Q1.0</td>
<td>Mixing Motor</td>
</tr>
<tr>
<td>Q1.1</td>
<td>Relay Control</td>
</tr>
</tbody>
</table>

III. CONCLUSION

Nowadays, automation systems are used for safe, quality and fast industrial production with the rapid development of industrial technology. PLC systems are widely used in automation systems. Usage of SCADA systems has increased with the expansion of the application areas of PLC. Industrial plants can be remotely monitored, controlled using SCADA with the PLC. Moreover, historical data of plants can be stored.

In this study, prototype and application of mortar mixing automation systems were realized. The system was controlled by a PLC and SCADA interface. Furthermore, the system can be remotely monitored and can be controlled with SCADA interface.

REFERENCES


Real Time Application of Sliding Mode Controller for Coupled Tank Liquid Level System

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Abstract— In this paper, real time application of a sliding mode control (SMC) is used for level control of experimental setup of liquid level system due to its properties such as robustness against large parameter variation and disturbances rejection. A well-tuned conventional proportional integral (PI) controller is also applied to the two coupled tank system for comparison with the SMC controller. Experimentation of the coupled tank system is realized in two different configurations, namely configuration #1 and configuration #2 respectively. In configuration #1, the water level in the top tank is controlled by a pump. In configuration #2, the water level in the bottom tank is controlled by the water flow coming out of the top tank. The performance of controllers is analyzed according to their tracking performance and error elimination capability for different references applied to the system. Experimental results prove that the SMC shows better trajectory tracking performance than PI controller in that the plant transient responses to the desired output changes have shorter settling time and smaller magnitude overshoot/undershoot. Robustness of the SMC with respect to water level variation and capability to eliminate external disturbances are also achieved.

Keywords— Liquid Level Control, Sliding Mode Control

I. INTRODUCTION

Liquid level control is one of the essential problems of process industry. In nuclear power plants, wastewater treatment plants, filling-disposal plants etc., high sensitive liquid level systems must be used to do complex and dangerous processes that are not done by humans. To achieve correct mixture ratio, adjust liquid flow between tanks precisely and to get high level performance from this systems, well-designed controllers must be also used. Due to their nonlinear system dynamics and can be effected disturbances easily, the control of liquid level systems are difficult. To overcome these difficulties and control this kind of systems in a desired efficiency, many control algorithms have been proposed by the researchers. Due to their simple structures, easy parameter adjustment and basic calculation knowledge needed P, PI, PID controllers are used to control liquid level of the tanks [1-3]. In the experimental application, classical P, PI, PID controllers are not sufficient for a precise control where sudden changes occur, parameter adjustment and fast response are needed. For these reasons, conventional P, PI and PID controllers are not a good choice for a nonlinear system. In control engineering and relevant areas, some nonlinear controllers have been developed to apply the systems that have nonlinear system dynamics. As an example, the backstepping controller has been presented to control the systems where system dynamics can be written in a lower triangular form [4-7]. Also, it has a recursive structure and its stability analysis can be proven based on Lyapunov stability theorem, the backstepping controller mostly preferred. On the other hand, all states of the system must be measured and in complex systems, more mathematical processes are needed to calculate the control input signal. Moreover, fuzzy controller is proposed where the system is not well defined and does not have an exact mathematical model [8]. Apart from these advantages, the fuzzy controller is not good enough to stabilize the system where the quick response is needed and the controller’s sensitivity need to be very high. Also, it is a rule based controller and there is no theorem to proof its stability criteria. As an another solution, SMC is proposed to control nonlinear systems. The SMC is a type of nonlinear controller and preferred for the systems where the controller must be very robust to model uncertainties and external disturbances [9-15]. In addition to this advantages mentioned on SMC, it has a simple structure and its stability criteria can be proven using Lyapunov stability theorem.

In this study, the liquid level control of coupled tank system is examined in experimental application using PI and SMC controllers for different reference inputs. Both controllers are compared in term of error elimination capability and robustness against to parameter uncertainty. The results prove that the SMC shows better trajectory tracking performance than PI controller. Also, the results show that SMC is really robust to model uncertainties occur in the system and good at eliminating the errors compared with the PI controller.

II. MODELLING AND CONTROL OF THE COUPLED TANK SYSTEM

A. Single Tank Model (Configuration #1)

Single tank system which consisting of the top tank is shown in Fig. 1. It is reminded that in configuration #1, the pump feeds into tank 1 and that tank 2 is not considered at all. Therefore, the input to the process is the voltage to the pump and its output is the water level in tank 1. The model of the single tank system determined by relating the volumetric inflow rate \( f_{i1} \) into tank and the outflow rate \( f_{o1} \) leaving through the hole at the tank bottom.
The volumetric inflow rate and the outflow rate to tank 1 can be expressed as [19],

\[ f_{i1} = \eta u(t) \]  
\[ f_{o1} = A_{o1} V_{o1} \]  

Where \( A_{o1} \) is the outlet cross sectional area, \( V_{o1} \) is the tank 1 outflow velocity, \( \eta = K_p / A_{i1} \) is constant, \( K_p \) is the pump volumetric flow constant and \( u(t) = V_p \) is the actual pump input voltage. The outflow velocity by using Bernoulli’s equation

\[ V_{o1} = \sqrt{2gL_1} \]  

(3)

where \( g \) is the gravitational constant on earth. As a remark, the cross-section area of tank 1 outlet hole can be calculated by,

\[ A_{o1} = \frac{1}{4} \pi D_{o1}^2 \]  

(4)

In the Eq. (4) \( D_{o1} \) is the tank 1 outlet diameter. Using Eq. (3) the outflow rate from tank 1 given in Eq. (3) becomes,

\[ f_{o1} = A_{o1} \sqrt{2gL_1} \]  

(5)

Moreover using the mass balance principle for tank 1, we obtain the following first-order differential equation in \( L_1 \),

\[ A_{i1} \left( \frac{dL_1}{dt} \right) = f_{i1} - f_{o1} \]  

(6)

where, \( A_{i1} \) is tank 1 inside cross-section area. Substituting Eq. (1) and (2) into Eq. (6) and it can be rearranged in the following form for the tank 1 system,

\[ \frac{dL_1}{dt} = \frac{KpV_p - A_{o1} \sqrt{2gL_1}}{A_{i1}} \]  

(7)

B. Coupled Tank Model (Configuration # 2)

A schematic of the coupled tank plant is depicted in Fig. 2.

In configuration #2 the pump feeds into tank 1, which in turn feeds into tank 2. As far as tank 1 is concerned, the same equation as the ones previously developed in section (2.A) is applied. However, the water level equation of motion in tank 2 still needs to be derived. In the coupled tank, the system states are the level \( L_1 \) in tank 1 and the level \( L_2 \) in tank 2. The outflow rate from tank 2 can be expressed as;

\[ f_{o2} = A_{o2} V_{o2} \]  

(8)

Tank 2 outflow velocity by using Bernoulli’s equation

\[ V_{o2} = \sqrt{2gL_2} \]  

(9)

As a remark, the cross-section area of tank 2 outlet hole can be calculated by,

\[ A_{o2} = \frac{1}{4} \pi D_{o2}^2 \]  

(10)

Using Eq. (9) and (10) the outflow rate from tank 2 given in Eq. (8) becomes

\[ f_{o2} = A_{o2} \sqrt{2gL_2} \]  

(11)

Using Eq. (5) the inflow rate to tank 2 is as follow

\[ f_{i2} = A_{i2} \sqrt{2gL_2} \]  

(12)

Moreover using the mass balance principle for tank 2, we obtain the following first-order differential equation in \( L_2 \),

\[ A_{i2} \left( \frac{dL_2}{dt} \right) = f_{i2} - f_{o2} \]  

(13)

Substituting Eq. (12) and (11) into Eq. (13) and it can be rearranged in the following form for the tank 2 system,
\[
\frac{dL_2}{dt} = -A_{o2} \sqrt{2 \frac{gL_2}{A_{o1}}} + A_{o1} \sqrt{2 \frac{gL_1}{A_{o2}}}
\]

(14)

III. SLIDING MODE CONTROLLER DESIGN FOR THE TANK 1

We assume that flow rates cannot be negative and we agree as follows,

\[
f \geq 0
\]

(15)

Therefore, following equation must satisfy as the flow rate to be above,

\[
L_1 \geq L_2
\]

(16)

Thus, the following equation can be written.

\[
L_1 = z_1, \quad L_2 = z_2
\]

(17)

\[
\frac{A_{o1} \sqrt{2g}}{A_{o1}} = k_1, \quad \frac{A_{o2} \sqrt{2g}}{A_{o2}} = k_2
\]

(18)

\[
k_1 = k_2 = k
\]

(19)

If writing to these assumptions in the dynamic model of the coupled tank system the following equations can be obtained.

\[
\dot{z}_1 = -k \sqrt{z_1} + \eta \mu
\]

(20)

\[
\dot{z}_2 = k \sqrt{z_1} - k \sqrt{z_2}
\]

(21)

\[
y = z_1
\]

(22)

The dynamics model of the coupled tank system is nonlinear. Therefore, in order to define the dynamics of the coupled tank system, the dynamic model subject to a transformation equation as follows.

\[
x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}, \quad and \quad x = T(z) \quad if \quad we \quad make \quad the \quad transformation,
\]

(23)

\[
x_1 = z_1
\]

(24)

\[
x_2 = \dot{z}_1 = -k_1 \sqrt{z_1} + \eta \mu
\]

(25)

The above equations will be obtained. Then the dynamics of the coupled tank system can be rewritten as shown below.

\[
\dot{x}_1 = x_2
\]

(26)

\[
\dot{x}_2 = -k \sqrt{\frac{z_1}{2}}
\]

(27)

Thus, the dynamics of the combined form of coupled tank system can be written as follows,

\[
\dot{x}_1 = x_2
\]

(28)

\[
\dot{x}_2 = f + \phi u = \frac{-k}{2 \sqrt{z_1}} (-k \sqrt{z_1} + \eta \mu)
\]

(29)

where,

\[
f = \frac{k^2}{2}
\]

(30)

\[
\phi = -\frac{k}{2 \sqrt{z_1}} \eta
\]

(31)

can be expressed. If we define the sliding surface \( s(t) \) as,

\[
s = \left( \frac{d}{dt} + \lambda \right)^{n-1} e = \lambda e + \dot{e}
\]

(32)

where \( \eta \) is the order of the system to be controlled, \( \lambda \) is a positive constant, \( e \) is the error. We take error as a reference and the measured difference and we obtained the following equation.

\[
e_1 = L_{eq} - L_1
\]

(33)

\[
e_1 = x_{eq} - x_1
\]

(34)

If we take the derivative of both sides of the Eq. (32) the following equation obtained.

\[
\dot{s} = \dot{\lambda} e + \dot{\dot{e}}
\]

(35)

Eq. (35) is employed as the expression written instead of the second order derivative of the error, following equations can be written,

\[
\dot{s} = \dot{\lambda} e + \left( \ddot{x}_{eq} - \ddot{x}_1 \right)
\]

(36)

Ideally, we want to sliding surface to be equal to zero. If sliding surface is zero than derivative of the sliding surface will be zero as following equations.

\[
0 = \dot{\lambda} e + \left( \ddot{x}_{eq} - \ddot{x}_1 \right)
\]

(37)

\[
0 = \dot{\lambda} e - f(x) - \phi(x)u_{eq}
\]

(38)

If \( u_{eq} \) in Eq. (38) left alone than Eq. (39) can be obtained.

\[
u_{eq} = \frac{-f(x) + \dot{\lambda} e}{\phi(x)}
\]

(39)

Considering the system parameters and disruptive we can get our control signal as follows.
Thus, the dynamics of the combined form of coupled tank system can be written as follows,

\[ u = u_{eq} + k_x \operatorname{sgn}(s) \]  \hspace{1cm} (40)

Substituting \( u_{eq} \) into Eq. (40) and it can be rearranged in the following form which is control signal for the tank 1 system,

\[ u = \frac{k \sqrt{L_1}}{\eta} - \frac{2\lambda \sqrt{L_1} \dot{e}_1}{k \eta} + k_x \operatorname{sgn}(s) \]  \hspace{1cm} (41)

IV. SLIDING MODE CONTROLLER DESIGN FOR THE TANK 2

Considering the dynamic of equality for tank 2, the following equations are considered to control tank 2.

\[ L_1 = z_2, \quad L_2 = z_1 \]  \hspace{1cm} (42)

\[ \frac{A_{o1} \sqrt{2g}}{A_{i1}} = k_1, \quad \frac{A_{o2} \sqrt{2g}}{A_{i2}} = k_2 \]  \hspace{1cm} (43)

\[ k_1 = k_2 = k \]  \hspace{1cm} (44)

If writing to these assumptions in place of the coupled tank system dynamic model equations are obtained from the following equation.

\[ \dot{z}_2 = -k \sqrt{z_2^2 + \eta u} \]  \hspace{1cm} (45)

\[ \dot{z}_1 = k \sqrt{z_2^2 - k \sqrt{z_1^2}} \]  \hspace{1cm} (46)

\[ y = z_1 \]  \hspace{1cm} (47)

Let \( x = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \), and the transformation \( x = T(z) \) such that,

\[ x_1 = z_1 \]  \hspace{1cm} (48)

\[ x_2 = \dot{z}_1 = k \sqrt{z_2^2 - k \sqrt{z_1^2}} \]  \hspace{1cm} (49)

Thus, the dynamics of the combined form of coupled tank system can be written as follows,

\[ \dot{x}_1 = x_2 \]  \hspace{1cm} (50)

\[ \dot{x}_2 = \frac{k}{2 \sqrt{z_2}} \dot{z}_2 - \frac{k}{2 \sqrt{z_1}} \dot{z}_1 \]  \hspace{1cm} (51)

\[ \dot{x}_2 = \frac{k}{2 \sqrt{z_2}} \left( -k \sqrt{z_2^2 + \eta u} \right) - \frac{k}{2 \sqrt{z_1}} \left( k \sqrt{z_2^2 - k \sqrt{z_1^2}} \right) \]  \hspace{1cm} (52)

\[ \dot{x}_2 = \frac{k \mu u}{2 \sqrt{z_2}} - \frac{k^2 \sqrt{z_2}}{2 \sqrt{z_1}} \]  \hspace{1cm} (53)

\[ \dot{x}_1 = \dot{z}_1 \]  \hspace{1cm} (54)

\[ \dot{x}_2 = f + \phi u = \frac{k^2 \sqrt{z_2}}{2 \sqrt{z_1}} + \frac{k \mu u}{2 \sqrt{z_2}} \]  \hspace{1cm} (55)

Where,

\[ f = -\frac{k^2 \sqrt{z_2}}{2 \sqrt{z_1}} \]  \hspace{1cm} (56)

\[ \phi = \frac{k}{2 \sqrt{z_2}} \eta \]  \hspace{1cm} (57)

It can be expressed. Define a sliding surface \( s(t) \) as,

\[ s = \left( \frac{d}{dt} + \lambda \right)^{n-1} e = \lambda e + \dot{e} \]  \hspace{1cm} (58)

Where \( n \) is the order of the system to be controlled, \( \lambda \) is a positive constant, \( e \) is the error. Error we take as a reference-measured, and we have obtained the following equation.

\[ e_2 = L_{2r} - L_2 \]  \hspace{1cm} (59)

\[ e_2 = x_{2r} - x_2 \]  \hspace{1cm} (60)

If we take the derivative of both sides of the Eq. (58) the following equation obtained.

\[ \dot{s} = \lambda \dot{e}_2 + \ddot{e}_2 \]  \hspace{1cm} (61)

Eq. (61) is employed as the expression written instead of the second order derivative of the error is obtained the following equation.

\[ \dot{s} = \lambda \dot{e}_2 + \left( \ddot{x}_{2r} - \ddot{x}_2 \right) \]  \hspace{1cm} (62)

Ideally, we want to sliding surface to be equal to zero. If sliding surface is zero then derivative of the sliding surface will be zero as following equations.

\[ 0 = \lambda \dot{e}_2 + \left( \ddot{x}_{2r} - \ddot{x}_2 \right) \]  \hspace{1cm} (63)

\[ 0 = \lambda \dot{e}_2 - f(x) - \phi(x)u_{eq} \]  \hspace{1cm} (64)

If \( u_{eq} \) in Eq. (64) left alone than Eq. (65) can be obtained.

\[ u_{eq} = -\frac{f(x)}{\phi(x)} + \frac{\lambda \dot{e}_2}{\phi(x)} \]  \hspace{1cm} (65)

Considering the system parameters and disruptive we can get our control signal as follows.

\[ u = u_{eq} + k_x \operatorname{sgn}(s) \]  \hspace{1cm} (66)
Substituting $u_{eq}$ into Eq. (66) the following equation which is control signal of the tank 2 can be obtained.

$$u = -\frac{kL_1}{\eta \sqrt{L_2}} + \frac{2\lambda \sqrt{L_2} \dot{e}}{k \eta} + k_s \text{sgn}(s)$$

(67)

Where, $k_s \text{sgn}(s)$ is switching control function. $k_s$, is the switching gain and $\text{sgn}(s)$ can be expressed given below [18].

$$\text{sgn}(s(t)) = \begin{cases} 
1 & s(t) > 0 \\
0 & s(t) = 0 \\
-1 & s(t) < 0 
\end{cases}$$

(68)

Using the controller law given in Eq. (41) and (67) in to Eq. (36) and (62), it follows that [17],

$$\dot{s} = -w_s \text{sgn}(s)$$

(69)

The state trajectories associated with this unforced discontinuous dynamics i.e eq (69) exhibit a finite time reachability to zero from any value of initial condition subject to the value of $w_s$ must be positive. Since system driven its states to zero in finite time, the desired level $y = z_1 = h_2$ and $y = z_1 = h_1$ in both tanks are regulated after a finite time by first order dynamics $\dot{y} + a_s(y - H) = 0$. Where $H$ is desired value of the output of tank. Hence, the output of both the tank will asymptotically converge to its desired value since $a_s$ is positive.

V. EXPERIMENTAL RESULTS

In the first experiment of configuration #1, the step+sinusoidal reference signal is applied for PI and SMC controllers given in Fig. 3 and Fig. 4 respectively. For the step reference signal part, PI controller has more overshoot and has longer settling time compared with the SMC. The time varying part of the reference signal, both controllers show the same performance in term of tracking the reference signal, under/overshoot and error elimination capability etc. On the other hand, SMC is generated the pump voltage with more chattering phenomena than the pump voltage generated by PI controller.

For the second experiment of configuration #1, the step+sawtooth reference signal is applied to show the responses and performance of both controllers shown in Fig. 5 and Fig. 7 respectively. The sawtooth reference signal is important due to consisting of the sudden and continuously changing part in the same period. For PI controller, it has more overshoot and longer settling time compared with SMC. Also, PI controller has continued to make overshoot through the continuously changing part of the sawtooth signal. Besides, SMC has no overshoot while tracking the step+sawtooth signal and has better performance in term of error elimination and robustness to parameter variations occur in the system.

The experimental results given for configuration #2, are realized using the step + trapezoidal reference signal for PI and SMC controllers shown in Fig. 6 and Fig. 8 respectively. In this section, the cascaded tank system is used to realize level control for different reference signals. For PI controller, it has longer rising and settling time. Also, PI controller has more overshoot than SMC controller. At the same time, SMC shows better performance for position tracking and also has given fast response the parameter variations.
VI. CONCLUSIONS

In this study, SMC has been designed and applied to two tank liquid level system in order to maintain a stable reference tracking for different reference signals for both configurations. The experimental results indicate that the proposed controller has better performance in term of error elimination capability, good reference signal tracking, robustness to parameter variations. It can be also noticed from the results obtained that SMC is reasonably prior to the classical PI controller for the levels that required to be kept at a constant level and following time varying reference signals very well.

REFERENCES


Real-Time Speed Control of BLDC Motor Based On Fractional Sliding Mode Controller

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Abstract— The design of the system used for brushless DC (BLDC) motor control in speed and position control is difficult due to the non-linear structure. Therefore, the designed controller is required to respond to these challenges and need high-efficiency operation. This paper presents the experimental validation of a robust speed control structure of a BLDC motor based on continuous sliding mode (CSM) and fractional sliding mode (FSM) controllers. The controllers have been tested for low and medium speed reference signals and amplitude values. Then, both controllers have been compared in term of tracking performance and error elimination and the results have been shown graphically. Experimental results prove that the FSM controller shows better trajectory tracking performance than CSM controller with high precision as well as good robustness against changes of references.

Keywords— BLDC motor, Continuous sliding mode control, Fractional sliding mode control, Speed control

I. INTRODUCTION

Parallel to the developments in the control areas, brushless DC motors are used in computers, automated office equipment, robotic applications, electro-mechanical systems and many precision machines. Brushless DC motors can be controlled more simply than other direct current motors and it has advantages such as high torque, high efficiency and small size. In addition, problems such as mechanical wear occur in the brushes and commutator by changing the position of the stator and rotor in the DC motor. And also maintenance of the brush takes a long time. But instead of brushes and commutator, BLDC motors use Hall Effect sensors [1]. Today, drivers have developed high processing ability and therefore robust control of BLDC motors are successfully carried out. The desired control algorithm is mathematically analysed for robust operation of the controller designed in accordance with, are tested in various computer programs and R & D work done. In the literature, various studies have been made for speed control of BLDC motors. In [2], is described a fuzzy logic approach for BLDC motor controller in variable speeds and the fuzzy logic tuner is used to adjust the gains of the PI controller and the results obtained in the simulation study showed less ripple under variation in system parameters with fast response times. Yu and Hwang have proposed an optimal PID controller and controller parameters are determined by linear quadratic regulator. The successes of the proposed method were compared with conventional PID controller and simulation and experimental results were given. Navidi et al. [4] proposed a method determined by ant colony search algorithm for PID controller parameters. They have demonstrated success with the simulation results of the proposed method in improving the step response characteristics such as reducing the steady-states error, settling and rise time, and maximum overshoot in speed control. Chen and Tang proposed a sliding mode current control scheme for pulsewidth modulation (PWM) brushless dc motor drives in their study [5]. In this scheme, an improved “equivalent control” method is used and they stated that the validity of this scheme is achieved by simulation and experimental results. Moshiri et al. proposed an approach that has the merit to determine the optimal structure and the inference rules of fuzzy sliding mode controller simultaneously [6]. The success of the proposed controller is provided with the simulation results. Wang et al. offered a stable hierarchical sliding-mode control method for a class of second-order under actuated systems [7]. They consider the system as two subsystems and defined a first-level sliding surface for each part. Also they defined a second-level sliding surface for these two first-level sliding surfaces and simulation results have shown the success of the proposed method and adaptive abilities for all kinds of extraneous disturbances.

The main advantages of sliding mode control are demonstrated in numerous examples and simulations. The history of this control structure; In 1977, after V. Utkin [8] compiler work, Sliding Mode Controller - SMC and Variable Structure Control - VSC methods are widely used in control
applications until today [9]-[19]. The aim of sliding mode control methods, especially in the real dynamic system; are
designed to drive the system states onto a particular surface in
the state space, named sliding surface. Once the sliding
surface is reached, sliding mode control keeps the states on
the close neighbourhood of the sliding surface. There are two
main advantages of sliding mode control. First is that the
dynamic behaviour of the system may be tailored by the
particular choice of the sliding function. Secondly, the closed
loop response becomes totally insensitive to some particular
uncertainties. The disadvantage of sliding mode control
method is a control signal that changes direction too much and
it is called chattering. Also chattering causes some problems
in practice such as damaging the component parts of the fast
moving systems, to causes fatigue in the controlled
system, significantly reduce the life of the system and also
cause unnecessary energy consumption. Various methods are
available to reduce this negative effect of chattering such as
filtering, discontinuous approach, saturation function and
fuzzy control. But this time the robustness of the sliding mode
control functionality is lost [12-14].

In this study, a fractional order sliding mode controller is
designed to reduce the effect of chattering and also to
maintain the high robustness and high accuracy features
sliding mode control.

II. BLDC MOTOR MODEL

The electrical and mechanical mathematical equation of
BLDC motor can be expressed as,

$$\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = -\frac{R}{L_1}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} - \frac{1}{L_1}\begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} + \frac{1}{L_1}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

$$\frac{d\omega_m}{dt} = \frac{1}{J_m}(T_e - B_m\omega_m - T_{Load})$$

$$\phi_e = \frac{p}{2}\phi_m$$

$$\begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} = \begin{bmatrix} f_{a}(\phi)\lambda\omega_m \\ f_{b}(\phi)\lambda\omega_m \\ f_{c}(\phi)\lambda\omega_m \end{bmatrix}$$

$$T_e = T_a + T_b + T_c$$

$$T_e = J_m\frac{d\omega_m}{dt} + B_m\omega_m + T_{Load}$$

$$T_{Load} = n^2f_j\frac{d^2\phi_m}{dt^2} + n^2B_2\frac{d\phi_m}{dt} + nF_c\frac{\phi_m}{|\phi_m|}$$

where ‘n’ is the gearbox reduction ratio, ‘B_m’ is frictional
coefficient of motor and load, ‘J_m’ is the motor inertia, ‘J_f’ is
the gearbox inertia, ‘F_c’ is Coulomb torque constant, ‘f_a(\phi)’,
‘f_b(\phi)’, ‘f_c(\phi)’ are functions having same shapes as back
emfs, ‘\lambda’ is represent the total flux linkage as the product of
number of turns and flux linkage/conductor, ‘\omega_m’ is the
angular speed of the motor, ‘\phi_m’ is mechanical angle of rotor,
‘\phi_e’ is electrical angle of rotor, ‘p’ is number of pole on rotor,
$L_i = L - M$, $L$ is the self inductance of the winding per phase,
$M$ is the mutual inductance per phase. $T_{Load}$ is written in the (6)
and it can be rearranged in the following form for each motor;

$$T_e = (J_m + n^2f_j)\frac{d^2\phi_m}{dt^2} + (B_m + n^2B_2)\frac{d\phi_m}{dt} + nF_c\text{sign}(\phi_m)(8)$$

BLDC motor state equations are written in the following form;

$$x(t) = Ax(t) + Bu(t)$$

$$y(t) = Cx(t)$$

where the states and input vector are chosen as;

$$x(t) = [i_a i_b i_c \omega \phi]^T$$

$$u(t) = [v_a v_b v_c T_{Load}]^T$$

the system matrices are given below,

$$A = \begin{bmatrix}
\frac{-R}{L_1} & 0 & 0 & f_a(\phi)\lambda \\
0 & \frac{-R}{L_1} & 0 & f_b(\phi)\lambda \\
0 & 0 & \frac{-R}{L_1} & f_c(\phi)\lambda \\
0 & 0 & 0 & \frac{-B_m}{J_m}
\end{bmatrix}$$

$$B = \begin{bmatrix}
\frac{1}{L_1} & 0 & 0 & 0 \\
0 & \frac{1}{L_1} & 0 & 0 \\
0 & 0 & \frac{1}{L_1} & 0 \\
0 & 0 & 0 & \frac{-1}{J_m}
\end{bmatrix}$$

$$C = [0 \ 0 \ 0 \ 1 \ 0]$$

III. CONTROL

In this section, the mathematical equations of designed
controller and its block diagram is given.

A. Continuous Sliding Mode Controller
The goal is to drive states of the system given (9), (10) in the set $S$ defined by:

$$S = \{ x: \tau(t) - \xi(x) = \varepsilon(x,t) = 0 \}$$  \hspace{1cm} (16)

where $\tau(t)$ is the time dependent part of the sliding function, containing reference inputs to be applied to the controller. $\xi(x)$ denotes the state dependent part of the sliding function, $\varepsilon(x,t)$. The derivation of the control involves the selection of a Lyapunov function $V(\varepsilon)$ and a desired form of derivative of the Lyapunov function such that closed-loop system is stable. The selected Lyapunov function is [20-22]

$$V = \frac{1}{2} \varepsilon^T \varepsilon$$  \hspace{1cm} (17)

which is positive definite, and its derivative is

$$\dot{V} = \varepsilon^T \dot{\varepsilon}$$  \hspace{1cm} (18)

The solution $\varepsilon(x,t) = 0$ will be stable if time derivative of the Lyapunov function can be expressed as [22]

$$\dot{V} = -\varepsilon^T D \varepsilon$$  \hspace{1cm} (19)

where $D$ is a positive definite matrix. Thus, the derivative of the Lyapunov function will be negative definite and this will ensure the stability. Eq. (18) and (19) lead to

$$\varepsilon^T (D \varepsilon + \dot{\varepsilon}) = 0$$  \hspace{1cm} (20)

A solution for this equation is

$$D \varepsilon + \dot{\varepsilon} = 0$$  \hspace{1cm} (21)

The expression for derivative of the sliding function is

$$\frac{d}{dt} \varepsilon = \frac{d}{dt} \tau - \frac{d}{dt} \xi$$  \hspace{1cm} (22)

where,

$$\xi = G \varepsilon(t)$$  \hspace{1cm} (23)

$G \in \mathbb{R}^{nxm}$ is gain matrices ,and

$$\dot{\xi} = G \dot{\varepsilon}(t)$$  \hspace{1cm} (24)

First, equivalent control is found by $\dot{\varepsilon} = 0$ and using (22) as

$$\dot{\varepsilon} = \dot{\tau} - \dot{\xi} = \dot{\tau} - (G \varepsilon(t) + GB \varepsilon_{eq}) = 0$$  \hspace{1cm} (25)

$$\varepsilon_{eq} = (GB)^{-1}(\dot{\tau} - G \varepsilon(t))$$  \hspace{1cm} (26)

Second, using (23) the control input to the system can be found by following:

$$\dot{\varepsilon} = -D \varepsilon = \tau - \dot{\xi}$$  \hspace{1cm} (27)

$$\dot{\tau} - (G \varepsilon(t) + GB \varepsilon_{eq}) = -D \varepsilon$$  \hspace{1cm} (28)

and the result of the short algebra can be written as

$$u = \varepsilon_{eq} + (GB)^{-1} D \varepsilon$$  \hspace{1cm} (29)

Third, from time derivative of the sliding function

$$\dot{\varepsilon} = \dot{\tau} - (G \varepsilon(t) + GB \varepsilon_{eq})$$  \hspace{1cm} (30)

multiplying both sides with $(GB)^{-1}$

$$(GB)^{-1} \dot{\varepsilon} = (GB)^{-1}(\dot{\tau} - (G \varepsilon(t) - u)$$  \hspace{1cm} (31)

and by using (25)

$$(GB)^{-1} \dot{\varepsilon} = \varepsilon_{eq} - u$$  \hspace{1cm} (32)

and finally when this equation is substituted in (29) the control is found as

$$u(t) = u(t^-) + (GB)^{-1}(\dot{\varepsilon} + D \varepsilon)$$  \hspace{1cm} (33)

$$t = t^- + \Delta , \ \Delta \rightarrow 0$$

The value of the control at the instant $t$ is calculated from the value at the time $t^- + \Delta$ and the weighed sum of the control error $\varepsilon$ and its time derivative. Control (33) is continuous function everywhere except in the points of discontinuity of the function $\varepsilon(x,t)$. When these equations are adapted for BLDC motor control system shown in Fig.1, the following equation can be written for the control loop as

$$u_c(t) = u_v(t^-) + (GB)^{-1}(\dot{\varepsilon}_v + D \varepsilon_v)$$  \hspace{1cm} (34)

![Fig. 1. Continuous sliding mode controller block diagram](image)

**B. Fractional Order Calculus**

The fractional-order differentiator can be denoted by a general fundamental operator $a D_t^p$, where $a$ and $t$ are the limits of operations. The fractional-order differentiator and integral are defined as follows,
it is seen that the CSM controller reference input and Fig. 4 are shown in Figs. 3 comparison of reference reduce the error and for system shown in Fig. 2. When these equations are adapted for BLDC motor control system shown in Fig. 2.

\[
\begin{align*}
\dot{D}_t^p & = \begin{cases} 
  \frac{d^p}{dt^p} & : p > 0 \\
  1 & : p = 0 \\
  \int_{0}^{t}(dr)^{-p} & : p < 0
\end{cases} \\
\end{align*}
\]  

(35)

where \( p \) is the fractional order which can be a complex number, however the constant \( p \) related to initial conditions. There are several mathematical definitions to describe the fractional derivatives and integrals [23],[24]. Between these definitions, here are two commonly used ones, i.e., the Grünwald–Letnikov (GL) and the Riemann–Liouville (RL).

The GL definition is,

\[
d_D^p f(t) = \lim_{h \to 0} \sum_{j=0}^{\left[ \frac{t-h}{h} \right]} (-1)^j \binom{p}{j} f(t-jh)
\]  

(36)

where \([.]\) means the integer part, while the RL definition is given as,

\[
d_D^p f(t) = \frac{1}{\Gamma(n-p)} \frac{d^n}{dt^n} \int_{0}^{t} \frac{f(\tau)}{(t-\tau)^{p-n+1}} d\tau
\]  

(37)

for \( n-1 < p < n \), \( \Gamma(.) \) is the Euler’s gamma function, \( a \) is the initial time and \( t \) parameter is used when the differential and integral are taken.

C. Fractional Order Sliding Mode Controller

In (34), if the derivative term expressed as a fractional order,

\[
u_s(t) = u_s(t^-) + (GB)^{-1}\left( \dot{D}_t^p \dot{e}_v + D \dot{e}_v \right)
\]  

(38)

When these equations are adapted for BLDC motor control system shown in Fig. 2.

Fig. 2. Fractional sliding mode controller block diagram

IV. EXPERIMENTAL RESULT

The performance of the both controllers are evaluated for the tracking capability of the references and the ability to reduce the error and rise time. Sinus and trapezoidal speed references are implemented to BLDC motor for performance comparison of both controllers and the experimental results are shown in Figs. 3-10. In the first experiment, 10 rpm sinusoidal speed reference is chosen for testing CSM and FSM controllers. As shown in Fig. 3 and Fig. 4, the FSM controller has fast rise time at the reference input in comparison with CSM controller. Although both controller have similar reference tracking capabilities and it is seen that the CSM controller is less sensitive to follow the reference. The maximum percentage errors of sine wave reference for CSM is 10.13% and for FSM 4.17% respectively. The results for sinusoidal speed reference at 1000 rpm are given in Fig. 5 and Fig. 8. Due to a reference signal which is slowly changing over time the tracking errors are close to each other. However FSM gives 0.4 sec rise time while CSM is 0.6 sec which is obviously much better.

In the second experiment, trapezoidal wave speed reference at 10 rpm is given for control of BLDC motor. The trapezoidal wave reference is important to test the performance of the controllers for sudden changes. It can be seen from Fig. 6 and Fig. 9 that, CSM gives 0.6 sec rise time while FSM is 0.5 sec. On the other hand, FSM have better performance than CSM when the trapezoidal wave reference sudden changes. The trapezoidal speed reference at 1000 rpm in Fig. 7 and Fig. 10 also shows the success of the FSM. Both controllers have similar reference tracking capabilities and have similar rise time at the starting point of trapezoidal wave. CSM was failed to show adequate performance at the moments of suddenly changes. FSM has been more successful than CSM at the any sudden change after the start.
Fig. 5. Continuous sliding mode 1000 rpm sinus ref.

Fig. 6. Continuous sliding mode 10 rpm trapezoidal ref.

Fig. 7. Continuous sliding mode 1000 rpm trapezoidal ref.

Fig. 8. Fractional sliding mode 1000 rpm sinus ref.

Fig. 9. Fractional sliding mode 10 rpm trapezoidal ref.

Fig. 10. Fractional sliding mode 1000 rpm trapezoidal ref.
V. CONCLUSIONS

In this paper, an experimental study on the application of CSM and FSM controllers to a BLDC motor under the different speed references was presented. The experimental results show that the FSM controller shows better steady state performance with better rise time, smaller speed error and having less overshoot when it compared to the responses of CSM. To conclude, the applied FSM controller results in better responses than CSM controller to control the speed of the BLDC motor under changing references.

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Design Of An Automated Device Programming System

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Abstract— The purpose of this study is to design a 3 axis automated programming machine for programming devices such as microcontrollers, EPROMs and CPLDs. While programming numerous devices, an automated system is needed. For his purpose, a prototype system is designed with 3 axis. The system consists of electronics, mechanics and vacuum parts. All of these are controlled by ATMEL's ATMEGA128 8 bit microcontroller using C language. In this study, microcontrollers are programmed which have 44 pins with TQFP package. With some modifications on hardware and software, the designed machine is able to program the devices which have different packages. Thanks to the user interface software, programming results which of the devices are programmed and which are not) can be seen on PC.

Keywords— Microcontroller, Robotic, Automated programming

I. INTRODUCTION

Robotics is a science that combines the technology and knowledge. Owing to the fast development of technology, the term robot, as an automatic machine that replaces humans, is not so clearly defined anymore. A robot is no longer just a humanoid robot, robotic hand at an auto assembly line, autopilot in aircraft, artificial intelligence built of living neurons or simple cleaning robot; it is also computer software that completes works, meant for humans. It is known that robots are built to replace humans at certain works [1].

The word “robot” was created in the twenties by Czech poet, Karel Capek, in one of his plays, a play that ended tragically. In the forties, another writer, Isaac Asimov, made robots the leading figures in his utopian novels. Since these times, robots have been subjects of imagination. The reality of industrial robots only came in the sixties when Joseph F. Engelberger introduced the PUMA robot as a freely programmable, universal, handling device. With it came automation in manufacturing industry, economic issues, and social concern about human labour replaced by machines. The versatility of these robot machines has been increasing, largely due to their continuously increasing ability of information processing. The main goal was the autonomous robot. But, as the application field for robots is widening, and the robot is coming out of the factory halls, new challenges are seen, and even a change of paradigm is taking shape [2].

It is clear that there are high expectations as to the future potential of robotics, even euphoric ones and somewhat unrealistically utopic [3]. On the other side, there are sceptical views, seeing robotics as one of the most powerful technologies of the 21st century, together with genetic engineering and nanotech [4] threatening to make humans an endangered species. A more moderate and realistic, but still fascinating approach has been taken by a study group, comprising of experts from engineering, medical, philosophical and legal sciences, discussing the provoking question whether humans could be substituted by robots [5].

II. LITERATURE REVIEW

The work shows the application of the manipulator to a printed-circuit-board driller system. The manipulator uses DC motors with permanent magnets. The design of the manipulator is based on microcontrollers to control the speed and position of the motors by using full bridge DC-DC converters with a pulse-width-modulation technique. The designed manipulator includes a PC that works as a user interface to load the file with the numeric control format for the driller. From this information, the PC generates the required position and speed commands for each servomechanism. The works describes in detail the software and hardware designed to measure and control the speed and the position of each servomechanism [6].

This work focuses on hardware and software interfacing for robot arm controller application. The aim of this study is to design and build a control system for position control for robot arm with an FPGA chip. This is closed loop control system. In which controller, drive circuits and the sensor circuit plays important role.

Plus Width Modulation (PWM) is used to control the speed of DC motor. The hardware functional block is to be design in software module with the help of VHDL coding. This hardware and software co-design is for five axes OW1 535 arm robot model for the movement of robot arm for pick and place application. The interfacing of different hardware blocks with software module for real time application is very challenging and demanding in every field to achieve better command over control through software only without disturbing the hardware. It reduced the manufacture time, performance, accuracy and lifetime of the particular system [7].
The position control algorithm for a belt-driven servomechanism of a laser cutting machine is described. A high-accuracy position tracking control procedure for systems with inherent elasticity due to the low-cost belt-driven servomechanism is derived based on a continuous sliding mode technique. The aim to robust position tracking control algorithm was tested by simulations and used in the industrial application of a motion controller for the CNC machine. Simulation and experimental results are also reported [8].

The goal of this study is to design a 3 axis automated microcontroller programming robot (AMPR) design were carried out.

III. MATERIAL AND METHODS

In this study is provided to program automatic way of programmable integrated circuits such as microcontroller, CPLD in. In the figure 1, automatic microcontroller programming robot (AMPR)’s block diagram is shown. Figure 2 shows a completed state.

AMPR consist of three axis; X, Y and Z. The movement of the X and Z axes with DC motor and Y-axis was carried out by using bipolar stepper motor (Figure 3 and Figure 4). Located on the microcontroller to be programmed with the aid of a vacuum tip to get from where it is the task of the Z-axis. In addition to the programming socket and programmed into the microcontroller it is also responsible for the drop to the point where the first received. The task of the X axis, the horizontal axis of the hosts on the Z-axis is to move left and right. The Y axis is to be programmed by moving back and forth on the horizontal axis provides the movement of the tray with the microcontroller.
Automatic operation of the system is generated by the C programming language is provided with the control algorithm.

The typology of the programming of a single microcontroller stages are listed below.

1) Placing the device that is to be programmed microcontroller
2) Initial settings
3) Programming the microcontroller
4) Putting the microcontroller from which it was first
5) The next transition to the microcontroller

In the first of the two leading operations once the single time is made in the initial phase.

IV. CONCLUSIONS

In this study is to design a 3 axis automated programming machine for programming devices. While programming numerous devices, an automated system is needed. For his purpose, a prototype system is designed with 3 axis. The system consists of electronics, mechanics and vacuum parts. Designed as a prototype AMPR instead of the desired functions of the program to the microcontroller has automatically. The modern structure, we can easily modify the possibility of functions and add some our new functions. The price the machine is a good choice for inventions and new applications in human life. We hope that this effort will prove useful for future robotics endeavours.

REFERENCES


High Gain Microstrip Patch Antenna Array Design For ISM 2450 MHz
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Abstract — A coplanar waveguide (CPW) fed patch antenna array is proposed in this paper. The resonance frequency of antenna is 2.47 GHz and is inside of ISM 2.45 GHz band. The dimension of proposed antenna is 230 mm x 91.5 mm. For substrate the material used is Roger 5870. The relative permittivity of the substrate material is 2.33. For increasing the gain, an array antenna has been designed. The antenna gain reaches up to 12 dB. The working has been simulated in the HFSS Ansoft. The reflection coefficient has been measured by Agilent Network Analyzer. The proposed antenna can be used in applications necessaries high gain such as wireless power transmission.

Keywords — Antenna, High gain, Antenna array, Microstrip patch antenna

I. INTRODUCTION
Antenna is the transitional structure between free space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or a waveguide, and it is used to transport electromagnetic energy from the transmitting source to the antenna, or from the antenna to the receiver [1]. Antennas are very important element of electromagnetic communication. An antenna performance can be described with some parameters. The resonance frequency describe the antennas working frequency. The researches of antenna are intensive in ISM Bands. Many of ISM Band centre frequencies are, 13.56MHz [2], 433.92MHz [3], 2.45GHz [4], 5.8GHz [5]. In other hand these antennas have different structures.
In the some application bandwidth is an important parameter [6] but in the other applications antenna gain may be more important parameter [7]. An application where antenna gain is important may be done array antenna working [8, 9].
Huang et al. has proposed an antenna design for triple-band biotelemetry with data telemetry (402 MHz), wireless powering transmission (433 MHz), and wake-up controller (2.45 GHz). The prototype of the rectenna was fabricated on a Roger 3210 substrate. The antenna type was PIFA and antenna gains were -7dB @402MHz, -11 dB @433MHz and -15dB @2450MHz [10]. Ali et al. has proposed a circularly polarized (CP) microstrip patch antenna that is function as a WLAN antenna in the 5.15–5.35 GHz and as a rectenna at 5.5 GHz. The antenna is 14.8 mm by 14.8 mm by 3 mm in size which can be readily integrated within a sensor circuit board [11]. Yang et al. presented two-port printed microstrip rectenna with compact structure for communication systems. An aperture-coupled dual polarization patch antenna is utilized as the receiving antenna. The max gain of antenna has been reported 7.0dBi @6.1 GHz [12].

The proposed antenna has been designed and successfully achieved outstanding performance within operating frequency of 2.45 GHz. Moreover, such antenna manage to achieve minimum reflection coefficient of S11 < -10dB which is suitable for industrial, scientific and medical (ISM) band applications. The length of proposed antenna is 230 mm and the width is 91.5 mm.

II. GEOMETRY OF DESIGNED ANTENNA

The antenna has been fabricated on a 1.6mm thick RT/Duroid 5870 substrate with a dielectric constant of 2.33 and loss tangent of 0.0012. Fig.1 is the proposed high gain microstrip patch antenna array. For antenna simulation has been used Ansoft HFSS.
present the second Impedance matching part of prosed antenna.

Fig. 2 Feeding part of coplanar feeded patch antenna array

Fig. 3 First Impedance Matching part of coplanar feeded patch antenna array

Fig. 4 Second Impedance Matching part of coplanar feeded patch antenna array

The parameters in fig. 1, fig. 2, fig. 3 and fig. 4 given is bellow described; a=39mm, b=48mm, c=2.5mm, d=4.25mm, e=12.5mm, f=6mm, g=5mm, h=4mm, i=7mm, j=7mm, k=4mm, l=3mm, m=5mm. The general dimension of proposed antenna is 230 mm x 91.5 mm. The Photograph on fabricated coplanar feeded patch antenna array is given in fig. 5.

III. RESULTS

The high gain microstrip patch antenna array has been fabricated and the S11 (return loss) parameter has been measured with Agilent Technologies Field Fox Microwave Vector Network Analyser N9926A. Fig. 6 shows the S11 results comparatively of the designed antenna as simulated values with Ansoft HFSS and measured values network analyser. The S11 value approximates to -14dB for 2.48 GHz. The Bandwidth is from 2.48GHz to 2.51GHz about 30MHz.

The antenna gain pattern is drawn with Ansoft HFSS. The max gain is 12 dBi for z direction.

The comparatively results with previous works are given in Table 1.
TABLE I

<table>
<thead>
<tr>
<th>Previous Works</th>
<th>Freq. (GHz)</th>
<th>Substrate</th>
<th>S11 (dB)</th>
<th>Gain (dB)</th>
<th>Dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectenna Application of Miniaturized Implantable Antenna Design for Triple-Band Biotelemetry Communication[10]</td>
<td>2.45</td>
<td>Roger 3210</td>
<td>-28</td>
<td>-1</td>
<td>10 x 10</td>
</tr>
<tr>
<td>A new circularly polarized rectenna for wireless power transmission and data communication[11]</td>
<td>5.5</td>
<td>Duroid 5880</td>
<td>-15</td>
<td>7.6</td>
<td>14.8 x 4</td>
</tr>
<tr>
<td>A Switchable UWB Slot Antenna using SIS-HSIR and SIS-SIR for Multi – Mode Wireless Communications Application[13]</td>
<td>5.5</td>
<td>Arlon AD270</td>
<td>-13.5</td>
<td>-5.3</td>
<td>32 x 24</td>
</tr>
<tr>
<td>A Compact and Broadband Microstrip Stacked Patch Antenna With Circular Polarization for 2.45-GHz Mobile RFID Reader[14]</td>
<td>2.45 $\varepsilon_{r1}=10$ $\varepsilon_{t1}=2.65$</td>
<td>Duroid 5870</td>
<td>-57</td>
<td>6.32</td>
<td>58 x 58</td>
</tr>
<tr>
<td>This Work</td>
<td>2.45</td>
<td>Duroid 5870</td>
<td>-14</td>
<td>7</td>
<td>230 x 91.5</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

In this work, high gain microstrip patch array antenna has been designed and fabricated that can operates at 2.45 GHz for ISM applications. Measured and simulated results show that the designed antenna has good performance over a bandwidth of 2.47–2.5 GHz. The gain has been measured a successful value such as 12 dBi for the designed antenna. The antenna has had an excellent performance of high gain. The proposed antenna can be used for energy harvesting and wireless power transfer applications.

REFERENCES

Separation of Wheat Seeds from Junk in a Dynamic System Using Morphological Properties

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Abstract— Wheat is the main food source of the humankind. After its harvest, it goes through many procedures from its separation from chaff to its packaging. With the development in technology, many of these procedures are realized with automatic systems which saves the manufacturer the cost of labour, time and provides the customer with more quality food. One of the main concerns of quality food production is to provide a customer with the product in its purest form which means the product must be separated from all foreign matters. In this study, type-1252 durum wheat seeds have been separated from junk using the morphological properties of wheat seeds through the uncompressed video image taken with the camera Prosilica GT2000c. The main references for the quality measurement of wheat seeds are the shape and the dimensions of a wheat seed. Aiming for high quality wheat grain storage with no junk, this article has adopted various image processing techniques from image preprocessing to feature extraction. The image processing has been realized in a computer environment and the results show that the image processing is successful and the detection of wheat seeds from junk was accurate.

Keywords— BlobAnalysis, Feature Extraction, Image Processing, Junk, Morphological Properties, Segmentation, Wheat Seed,

I. INTRODUCTION

Food supply is one of the most essential materials for the survival of human beings. Wheat, which is the most fundamental material of amylaceous products like bread and pasta, is also one of the main food supply for human beings. It is important for the food industry to provide quality goods which includes wheat grains. After its harvest, wheat seeds go through many procedures from its separation from chaff to its packaging and they are stored in warehouses to be sold at specified intervals [1]. The inspection and the classification of good quality wheat grains can be done by manually through a series of instrumental or chemical analysis. Obtaining good quality wheat product through these tests and analysis is subjective, time consuming, less efficient, costly and the safe inspection of food without damaging its structure is nearly impossible [2], [3].

In recent years, it has become imperative to use automatic systems in the inspection and classification of wheat seeds to eliminate all those adverse conditions mentioned. With rapidly developing computer technologies, machine vision systems and image processing techniques have become one of the most popular research areas in wheat inspection and classification, because they have the ability to visually characterize wheat grains by their physical attributes and the process is objective, speedy, most efficient, cheap, repeatable and harmless to wheat seeds [2], [3].

Through the last years, many researchers have evaluated machine vision and image processing techniques if they really meet the expectations for the inspection and classification of the quality of wheat. There have been many studies about the determination of the properties of single wheat seed, separation of one type wheat from another or identification of damaged wheat seeds, but there have not been many researches about separating the wheat seeds from non-wheat seeds [1]. In a study conducted by Pourrez et al., nine different wheat classes growing in Iran have been classified according to its textural properties extracted from Gray Level, GLCM (Gray Level Co-occurrence Matrix), GLRM (Gray Level Run-length Matrix), LBP (Local Binary Pattern), LSP (Local Similarity Pattern) and LSN (Local Similarity Numbers) matrices and classified using LDA (Linear Discriminate Analysis) [4]. Xia et al. classified a single type wheat with regards to its quality by accounting its 7 morphological properties and 6 colour properties [3]. In an article written by Gűneş et al., it is explained the varieties of wheat growing in Turkey are classified according to its textural analysis using GLCM and LBP methods and k-Nearest Neighbour type classifier [5]. In a study conducted by Babalik et al., variety of wheat classes are identified with 9 morphological and 3 colour features using M-SVM (Multiclass Support Vector Machines) and BPSO (Binary Particle Swarm Optimization algorithm) [6]. In another study, Farahani tried to determine the best potential morphologic features to classify 5 different types of durum wheat [7]. Manickavasagan et al. tried to measure the ability of a machine vision system with a monochrome camera to classify the different types of western Canadian wheat types by using bulk sample analysis [8]. Williams et al. have evaluated two different digital image analysis (DIA) approaches to quantifying wheat seed shape for exploring trait correlations and QTL (Quantitative Trait Loci)
mapping [9]. All these studies generally have been made with the purpose of classifying different types of wheat. However, there is also a small number of studies about purification of wheat from its chaff and other impurities. One of these studies is made by Ebrahimi et al. to propose a machine vision automatic grading system which separates the wheat from the impurities within [1]. The objective of another study conducted by Paliwal et al. is to develop an algorithm which classifies 5 different types of Canadian wheats and also differentiates the wheats from non-wheat materials [10]. In another study, FN Chen et al. have developed an image processing algorithm which determines black germ wheat [11]. It can be seen from these examples that so few of the studies are about purification of wheat from non-wheat materials. Also, all of these studies are conducted in stationary environment and the possible outcomes are not known for a non-stationary environment.

In this study, our objective is to obtain good quality type-1252 durum wheat grains by separating the impurities from wheat grains in a dynamic system using image processing techniques. The process stages we used in this study are shown in Fig.1.

II. MATERIAL AND METHODS

A. Image Acquisition

The system used consists of a band-wheel system where the durum wheat grains are moving upon, image acquisition camera Prosilica GT2000C, and illumination apparatus with a shady box stand for preventing the shadow formation on the background.

Prosilica GT2000C camera is a 2.2 megapixel, RGB camera with 2048 x 1088 resolution, CMOS type sensor, 53.7fps maximum frame rate at full resolution and efficient operation temperature range between -20 °C and +65 °C [12]. The camera has been placed atop the illumination apparatus and daylight coloured powerleds have been placed around the camera. Under the illumination apparatus there is a ground glass around the camera lens so that the light can refract uniformly. The camera and the light illumination apparatus has been placed above a shady box so that the outside light does not affect the wheat grains and shadow formation can be prevented.

The camera views a 8 cm x 10 cm area inside the box and the 5 sec uncompressed video obtained from the camera is transmitted to the image processing computer software with an ethernet cable. The system used for this study is shown in Fig.2. Also, a frame sample of the video acquired is shown in Fig. 3.

Fig. 1 The process stages that were followed in the study

Fig. 2 Dynamic system used for acquiring video sample of durum wheat grains with impurities

Fig. 3 Frame sample of the video visualizing durum wheat grains with impurities
B. Image Preprocessing and Segmentation

The obtained video has been separated into frames and all the frames have been subjected to same processes. First the colormap of the images adjusted suitably after several trials so that the image segmentation is successful. The image with adjusted colormap is shown in Fig. 4.

![Fig. 4 The frame sample of the video with adjusted colormap](image)

After adjusting the colormap, the images are turned into gray images and subjected to a 5 x 5 median filter. Median filtering is a non-linear filtering process which offers an effective noise reduction without blurring the image [3]. After the filtering process, the background is subtracted from the image with “top-hat” operation so the background noise does not affect the image processing. The median filtered image with background subtraction is shown in Fig. 5. Then, morphologically “open” and “close” operations have been applied to the images to smooth the boundaries of the objects and the images have their contrast values adjusted to reduce edge detection errors. The frame sample after several morphological operations is shown in Fig. 6. Lastly, they were converted to binary images using an appropriate threshold value. The binary image of the frame sample is shown in Fig. 7.

Duru\textsuperscript{m} wheat grains and other non-wheat materials reside on the band in a random order so the grains can touch other grains or the other non-wheat materials. While the morphological operation “erode” can shrink the objects, thus maybe separate them. However, if the objects are touching each other they can still be connected despite the touching area is really small. In such conditions, a watershed algorithm is needed. The watershed transform is a segmentation algorithm that can divide the image into multiple regions where the darker colours represent a region with lower altitude and lighter colours represent a region with higher altitude topologically [13]. Thus, a watershed segmentation algorithm used for properly segment all the objects from each other. To apply watershed transform efficiently for segmentation, the first step is to apply the distance transform which labels each existing pixel according to the distance with the nearest boundary pixel in a binary image [13]. Although the distance transform is successful for segmenting round and simple touching objects, it is not successful for kernels with irregular shapes [13]. The reason why it is not successful to segment kernels with irregular shapes is because large number of local minima occur due to large clusters of objects which causes over-segmentation [14]. So, in our study, we used a watershed segmentation algorithm with extended-minima transform to segment the durum wheat grains where the extended-minima transform can produce markers for objects where local minima with greater depth than \( h \) are marked and where local minima with less depth than \( h \) are eliminated. By using minima imposition technique, we create minima at the specific locations associated with the markers [14]. After this procedure, watershed segmentation is applied which results in perfect segmentation for touching grains. The edge detected binary sample image after watershed segmentation with extended-minima transform is shown in Fig. 8.

C. Feature Extraction

The blob is the region of connected pixels of an object and blob analysis is the method which investigates these regions and provides us the information about the regions’ several properties. It is used for feature extraction processes [15]. The blob analysis algorithm distinguishes the pixels according to their values and labels them into 2 categories. The foreground
category is generally the pixels with a non-zero value and the other category is the background where the pixels with a zero value belong. Thus, the blob analysis algorithm measures several properties of the object regions in the image [15].

After the segmentation process, blob analysis algorithm is used for the feature extraction process to measure the properties of wheat grain regions. In our study, 9 morphological features are used for the separation of durum wheat grains from impurities. These features which are extracted directly by blob analysis are area, major axis, minor axis, perimeter equivalent diameter, eccentricity. Features which can be calculated from the others are roundness, shape factor, compactness [6]. The features used for this study and their definitions are shown in the Table I [6], [7], [16].

<table>
<thead>
<tr>
<th>Feature</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Number of pixels in the region</td>
</tr>
<tr>
<td>Major Axis</td>
<td>The length (in pixels) of the major axis of the ellipse</td>
</tr>
<tr>
<td>Minor Axis</td>
<td>The length (in pixels) of the minor axis of the ellipse</td>
</tr>
<tr>
<td>Perimeter</td>
<td>The length (in pixels) around the boundary of the region</td>
</tr>
<tr>
<td>Equivalent Diameter</td>
<td>The diameter of a circle with the same area as the region</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>The ratio of the distance between the foci of the ellipse and its major axis length</td>
</tr>
<tr>
<td>Roundness</td>
<td>$4 \cdot \text{Area}/\pi\cdot (\text{Major Axis})^2$</td>
</tr>
<tr>
<td>Shape Factor</td>
<td>$4 \cdot \pi \cdot \text{Area}/\text{Perimeter}^2$</td>
</tr>
<tr>
<td>Compactness</td>
<td>$\sqrt{4 \cdot \text{Area}/\pi}/\text{Major Axis}$</td>
</tr>
</tbody>
</table>

Fig. 6 Frame sample after several morphological operations

Fig. 7 Binary image of the frame sample

Fig. 8 The edge detected binary image of the frame sample after watershed segmentation with local-minima transform
III. RESULTS AND DISCUSSIONS

After feature extraction, mean and standard deviation values of the properties have been calculated. Durum wheat grains are separated from the impurities by a simple algorithm which uses the calculated results as ranges. The mean and the standard deviation values of the properties are given in Table II.

The algorithm determines the particles which are accepted as durum wheat grains by comparing the properties of every single object within a range specified using the mean values and standard deviation values of the properties. If all the properties of a single object is within the specified range, then the object is a durum wheat grain. If not, then the object is non-wheat material. The obtained result is 73.52% accuracy for the separation of non-wheat materials from durum wheat grains which is an optimistic result for image processing of a dynamic environment, because it is much more complex than image processing of a single image of a stationary environment. If a more complex and more efficient classification algorithm is used for the separation of durum wheat grains from impurities, than the accuracy result will be improved.

<table>
<thead>
<tr>
<th>Features</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>151,151</td>
<td>33,585</td>
</tr>
<tr>
<td>Major Axis</td>
<td>88,590</td>
<td>17,901</td>
</tr>
<tr>
<td>Minor Axis</td>
<td>38,357</td>
<td>7,077</td>
</tr>
<tr>
<td>Perimeter</td>
<td>172,485</td>
<td>35,456</td>
</tr>
<tr>
<td>Equivalent Diameter</td>
<td>192,451</td>
<td>42,761</td>
</tr>
<tr>
<td>Eccentricity</td>
<td>0,892</td>
<td>0,056</td>
</tr>
<tr>
<td>Roundness</td>
<td>0,026</td>
<td>0,011</td>
</tr>
<tr>
<td>Shape Factor</td>
<td>0,068</td>
<td>0,023</td>
</tr>
<tr>
<td>Compactness</td>
<td>0,160</td>
<td>0,027</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

As it is shown in literature, previous studies conducted are not about the purification of wheat from non-wheat materials generally but about classification of wheat varieties. Also, the studies conducted in a dynamic environment are almost non-existing. In this study, the objective has been to obtain good quality type-1252 durum wheat by separating the impurities from wheat grains in a dynamic system using image processing techniques. These processes are image preprocessing for image enhancement, watershed transform with extended-minima transform for segmentation and blob analysis for feature extraction.

In this study, after segmentation and feature extraction processes, a simple algorithm is used for the separation of non-wheat materials from durum wheat grains. The reason for using a simple algorithm is because it was a start for dynamic environments which is not the case for many researches in literature. However, the obtained result is not bad for a start. In future studies, we will use different and more efficient classification models to obtain perfect classification results.

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REFERENCES

Defected Ground Structure-Based Ultra-wideband Triangular Patch Antenna

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Abstract—A design of ultra-wideband monopole patch antenna is presented in this study. The design consists of a radiating triangular patch antenna (TPA) fed through a 50 Ohm microstrip transmission line (MTL) and defected ground structure (DGS). The triangular monopole is matched to MTL with inserting a thin strip line. The performance of the proposed antenna is numerically investigated using method of moments (MoM) and verified through measurements. Based on the measured results, the antenna operates over large frequency range of 2.6-18.2 GHz at -10 dB. The proposed antenna has well characteristics in terms of radiation pattern, peak gain and total efficiency across the operating ultra-wideband frequency range. Furthermore, the antenna system is suitable for near-millimetre wave applications, since the operating band reaches to 18.2 GHz.

Keywords—Antennas, patch antennas, antenna designing, ultra-wideband (UWB), defected ground structure (DGS)

I. INTRODUCTION

The ultra-wideband systems have received considerable attention in recent years due to allowing signal transmission in a large bandwidth with a low energy level. Radar imaging, mobile and satellite communications, multimedia streaming, biomedical imaging are the most important application areas of ultra-wideband systems [1-5]. The ultra-wideband systems have been further studied especially since Federal Communications Commission (FCC) approved the unlicensed use of the frequency range of 3.1–10.6 GHz for low power emitting implementations [6].

Patch antennas are widely used in the wireless systems due to various advantages such as low profile, small size, light weight, conformability to mounting host and capability of integration into the arrays. Owing to these advantages, the printed antennas have been integrated to the latest wireless communications of wireless local area network (WLAN), long term evolution (LTE) and worldwide interoperability for microwave access (WiMAX) standards, and ultra-wideband systems. Designing an appropriate antenna is the most important part of ultra-wideband applications because it effects the whole system performance.

There are several antenna structures that can be used for ultra-wideband systems such as the Vivaldi antenna [7], log periodic antenna [8], spiral antenna [9] and monopole antenna [10-18]. Monopole designs show inherently wideband behaviour as well as omni-directional radiation pattern. Therefore the printed forms of that designs can be successfully exploited for ultra-wideband systems. Over the past years, several monopole antenna structures, such as rectangular [10], circular [11], elliptical [12], conical [13], tapered [14, 15], slot-loaded [16-18] and defected ground [19-22] configurations, have been suggested for ultra-wideband applications.

The popularity of defected ground structure (DGS) in antenna study has increased immensely [19-22]. The DGS is basically obtained by properly modifying the ground plane of a patch antenna. Thus compact designs with high characteristics of especially wideband and gain can be achieved.

In this study, an ultra-wideband triangular patch antenna (TPA) that consists of a triangular monopole is designed. The triangular monopole is positioned on a rectangular DGS. The triangular radiating monopole patch is fed through a microstrip transmission line (MTL). The TPA is modelled in HyperLynx 3D EM simulation software based on method of moments (MoM) and fabricated for measurements. The TPA with a small size of 23x31 mm$^2$ operates across 2.6 GHz to 18.2 GHz based on measured results.

II. THE PROPOSED DGS-BASED TPA STRUCTURE

The 3D geometry of the TPA model is depicted in Fig. 1 and its dimensions are given in Table I. The TPA structure is composed of a 14x23 mm$^2$ triangular monopole patch fed by 50 Ohm MTL and a 17x23 mm$^2$ rectangular DGS. The radiating plane is placed over a 1.6 mm height substrate with 4.4 relative dielectric constant on the DGS. Therefore, the TPA has a total dimension of 23x31x1.6 mm$^3$. In order to improve the impedance matching, a 1 mm thin strip line is inserted between triangular radiating patch and the MTL.
Fig. 1. The 3D geometry of the TPA a) perspective view, b) front view, c) side view

![3D geometry of the TPA](image)

Table I

<table>
<thead>
<tr>
<th>Dimensions of the TPA (Unit: mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
</tr>
<tr>
<td>1.6</td>
</tr>
</tbody>
</table>

III. THE TPA DESIGN PROCEDURE

In design process, different patch forms are assayed in order to achieve an ultra-wideband operation. To further understand the evaluation of the proposed antenna system, the designing steps are investigated in four cases: Case I, II, III and IV as illustrated in Fig. 2. The simulated $S_{11}$ parameters related to the cases are accordingly shown in Fig. 3. In Case I, the design procedure is started with a 14x23 mm$^2$ rectangular radiating patch fed by 50 Ohm MTL and a DGS. The DGS is obtained by shortening the ground plane size of 31x23 mm$^2$ to 17x23 mm$^2$ so as to obtain an effective radiation. Since the radiation field occurs mainly between the radiating patch and the ground edges facing to each other, modifications on these edges can yield a satisfactory results. Therefore, in Case II, the radiating edges facing to the fixed DGS are triangularly trimmed to increase the impedance bandwidth as can be seen in Fig. 3. Once a better results are achieved by this way, the triangular cut’s angle with the DGS is increased to further improve the impedance matching as in Case III. Note that the 50 Ohm MTL uniformly continues from the port to the input of the triangular radiating patch. Owing the radiation starting from the end of DGS, a thinner strip is needed to match the input impedance of the triangular radiating patch to the MTL. A strip is hence designed between those in Case IV which is the final form of the designed antenna system.

IV. THE CURRENT MECHANISM OF THE TPA

The simulated surface current distributions of the TPA at the frequency points of 2.7 GHz, 8.1 GHz and 11.9 GHz are presented in Fig. 4. From the figure, the current distributions for these frequencies vary in similar to each other. As mentioned above in Section III that the radiation field comes about the facing edges, it can also be observed from the current distributions, the source current of that radiation is mostly concentrated at those edges. In addition, the majority of the current intensifies at the side edges of the matching strip line since it behaves as a resonator. This means that it does not only match the input impedance but also highly contributes to the radiation.

![Simulated S11 plots](image)
Fig. 4. Surface current distributions of the TPA: a) 2.7 GHz, (b) 8.1 GHz, (c) 11.9 GHz

V. FABRICATING A PROTOTYPE OF THE TPA

The prototype of the TPA is shown in Fig. 5. The antenna model is etched with the use of a computer numerical control (CNC) machine on a double side 1.6 height FR4 substrate with a relative dielectric constant of 4.4 and a tangent loss of 0.017. The measurements are carried out by the agency of Keysight Technologies N5224A PNA network analyser. The measured $S_{11}$ parameters in comparison with the simulated ones are plotted in Fig. 6. Based on the measured results, the TPA operates between 2.6 GHz and 18.2 GHz. It should be noticed that discrepancies between the simulated and measured curves might be attributed to the small mismatches of geometry, dielectric thicknesses, copper cladding and feeding between the simulated models and the prototype.

Fig. 5. The photograph of the fabricated TPA

Fig. 6 Measured and simulated $S_{11}$ parameters of the prototyped TPA

VI. RADIATION, GAIN AND EFFICIENCY CHARACTERISTICS

Simulated 2D gain radiation patterns of the TPA at the frequency points of 2.7 GHz, 8.1 GHz and 11.9 GHz are illustrated in Fig. 7. The maximum gains are 2.14 dB (in direction of 180° on x-z plane), 2.2 dB (in direction of 185° on y-z plane) at 2.7 GHz; and 2.42 dB (in direction of 90°/270° on x-z plane), 1.9 dB (in direction of 320° on y-z plane) at 8.1 GHz. Likewise, they are 1.6 dB (in direction of 145°/215° on x-z plane) and 0.2 dB (in direction of 45°/315° on y-z plane) at 11.9 GHz.
VII. CONCLUSIONS

In this work, we presented a compact ultra-wideband monopole patch antenna design operating over a large frequency range of 2.6–18.2 GHz. The monopole TPA fed via a MTL is built on a half-length DGS. The whole antenna system has a small size of 23x31 mm². A thinner strip line is inserted between the triangular monopole and the MTL to improve the impedance matching. The proposed TPA is verified by simulation and validated through measurement. The TPA has superior characteristics of larger bandwidth than the regulated ultra-wideband of 3.1–10.6 GHz, near omnidirectional pattern, uniform gain and high efficiency. In conclusion, since the TPA operates up to 18.2 GHz it can be also utilized for near-millimeter wave applications.

ACKNOWLEDGMENT

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Speech Denoising using Common Vector Analysis in Frequency Domain

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Abstract—Signal denoising approaches on data of any dimension largely relies on the assumption that data and the noise components and the noise itself are somewhat uncorrelated. However, any denoising process heavily depending on this assumption retreats when the signal component is adversely affected by the operation. Therefore, several proposed algorithms try to separate the data into two or more parts with varying noise levels so that denoising process can be applied on them with different parameters and constraints. In this paper, the proposed method separates the speech data into magnitude and phase where the magnitude part is further separated into common and difference parts using common vector analysis. It is assumed that the noise largely resides on difference part and therefore denoised by a known algorithm. The speech data is reconstructed by combining common, difference and phase parts. Using Linear Minimum Mean Square Error Estimation algorithm on the difference part, excellent denoising results are obtained. Results are compared with that of the state of the art in well-known speech quality measures.

Keywords—speech, denoising, cva, subspace, frequency domain

I. INTRODUCTION

For decades, as cognitive science penetrated into automation systems, voice automated applications like voice directed banking, voice signatures, intelligent homes; voice recognizing mobile-phone apps and such became both possible and popular. All voice applications somewhat necessitate high quality voice signals, mostly in digital form, imputering voice denoising algorithms. All naturally collected signals carry some noise energy weather from electronics/transmission or unrelated background signals. Voice denoising aims to improve signal quality, voice intelligibility or do both, achieving that with minimal loss in signal energy.

Although the voice denoising methods can be separated into two as single and multiple channel algorithms, researchers mostly focused on single channel because of incomparably higher number of encounters of such. Spectral subtraction, noise estimation, Wiener deconvolution/filtering, statistical and subspace based methods are considered as mainly single channel, notwithstanding the fact that they can be and are also employed in multichannel systems. In this paper, a method based on common vector analysis (CVA) is proposed. Therefore, brief methodology of other well-known subspace is given for comparisons.

Subspace methods rely on the expectation that the noisy data can be separated into two or more component where noise can be handled more efficiently within. A Singular Value Decomposition (SVD) based approach, proposed by Dendrinos et al. [1], uses the expectation that, after factorization of the data into sub-data, noise energy concentrates in vectors corresponding to smaller singular values. In the simplest denoising approach these are zeroed and voice data is recomposed. This technique is improved by Jensen et al. [2] for colored noise on which the former method has somewhat failed to reduce. On the other hand, their method with high computational complexity had several constraints for controlling residual noise. Ephraim et al. [3] aimed to optimize the estimator that minimizes distortion caused by residual noise. Noisy signal is separated into noise and signal subspaces using Karhunen Loeve Transform (KLT) whereby zeroing the components in noise subspace and restructuring the signal subspace using a gain function. Components in subspaces are recombined again to obtain denoised signal through inverse KLT. Mittal et al. [4] and Rezayee et al. [5] expanded this work for colored noise. They obtained better results by employing different KLT matrices and converging covariance matrix of the noise vectors to a diagonal matrix respectively.

Common Vector Approach (CVA) is a subspace method used in recognition applications. In CVA, training data representing each subject to be discriminated are used to form its own class. In a speech recognition application, ambient noise, ages and genders of speakers result in differences within a class [6]. CVA is based on the common component of those, basically by removing these differences within the class. This component is called the common vector. It has been employed in speaker recognition [7], speech recognition [8]-[10], face recognition [11], fault detection in electrical motors [12], spam e-mail detection [13]. CVA has also been used in image denoising [14].

II. COMMON VECTOR APPROACH

When differences between feature vectors in a class are removed, the remaining vector which consists of features invariant within the class is called the common vector. A
feature vector is then, presumed to be a sum of common and difference components. If the number of feature vectors \( m \) is greater than the dimension \( n \) of the vectors, then this is called a sufficient case \( m > n \). In the sufficient case, the common vector is the mean vector. The insufficient case occurs when the vector dimension is larger than or equal to the number of vectors \( n \geq m \), which is the case in most practical applications where, for example, too few image blocks with many pixels each exist. In general, it covers the setups where number of samples is less than the sample dimension. Since we are interested in such setups, only insufficient case of CVA is described in the following.

Let the feature vectors in a pattern class be linearly independent \( a_1, a_2, \ldots, a_m \). Each vector can be written as

\[
a_i = a_{i, \text{diff}} + a_{i, \text{comm}}, \quad i = 1, 2, \ldots, m
\]

where \( a_{i, \text{comm}} \) and \( a_{i, \text{diff}} \) are common vector of the class and difference vector per \( a_i \) respectively. The covariance matrix for the class is

\[
\Phi = \sum_{i=1}^{m} (a_i - a_{\text{avg}})(a_i - a_{\text{avg}})^T
\]

where \( a_{\text{avg}} = \frac{1}{m} \sum_{i=1}^{m} a_i \) denotes the mean of the vectors in the class. In insufficient case \( n \geq m \), \( n - m + 1 \) of the eigenvalues will be zero and corresponding eigenvectors \( u_j \) span the indifference subspace \( B^\perp \), while the remaining eigenvectors span the difference subspace \( B \) where \( B \) and \( B^\perp \) are orthogonal. The common vector of the class can be found by projecting any feature vector onto the indifference subspace \( B^\perp \) using

\[
a_{\text{com}} = P^\perp a_i, \quad i = 1, 2, \ldots, m.
\]

The projection matrix \( P^\perp \) is calculated using eigenvectors \( u_j \) that correspond zero valued eigenvalues (spans \( B^\perp \)) via

\[
P^\perp = \sum_{j=1}^{n-m+1} u_j u_j^T.
\]

The subspace methods other than CVA requires the inverse of the covariance matrix \( \Phi \) [15]. However, \( n \geq m \) inhibits the calculation of inverse of \( \Phi \) whereas CVA does not have this problem.

It is expected that noise mainly reside within the difference components when it is uncorrelated between class vectors. Therefore, it is imperative to construct classes as correctly as possible. When class information of the vectors is not available, classes should be constructed by collecting similar vectors into a data set matrix for each evaluated vector whose common vector is to be found. When the input data is a stream or can be handled as a stream with bounds, for example, classes can be constructed by searching similar vectors within a reasonable time range.

Since the raw vectors in speech data are selected to be sample frames of length \( n \), the words vector and frame are used interchangeably used within this paper.

### III. PROPOSED ALGORITHM

The denoising algorithm proposed in this paper relies on the intuition that the spectral content of the speech does not abruptly change and changes are mostly noise related. Approach is similar to time averaging of Fast Fourier Transform (FFT) data in digital spectrum analyzers. On the other hand, the overlapping ratio is the highest in the proposed algorithm. As illustrated in the Fig. 1, frames are picked from original speech data stream by a sliding Hamming window of width \( n \)

\[
w_i = 0.54 - 0.46 \cos(2\pi i/(n-1)), \quad i = 1, 2, \ldots, n
\]

which picks 1 sample for each subsequent frame. Although not required, it is logical to select \( n \) to correspond approximately 4 ms speech data since spectral characteristics of speech may greatly change for longer intervals. We conducted some tests for determining optimal frame length, as explained in the following section and concluded that 4 ms is adequate.

For each frame to be denoised, a class is constructed by picking \( m \) most spectrally similar Hamming windowed frames within its neighbourhood. Obviously entire data stream can be used for selecting the frames and constructing the class. In our experiments, it is determined that a neighbourhood size that contains \( 2n-1 \) frames, \( x'_i \), including the current frame to be denoised, is sufficient for both required number of vectors for the class and reasonable computational complexity. FFT of these \( 2n-1 \) frames are calculated and their magnitude and phase components are separated as

\[
b_k = |FFT\{x'_i\}|
\]

\[
p_k = \langle FFT\{x'_i\} \rangle.
\]

\( m-1 \) magnitude frames that are most similar to the magnitude frame of the current frame (the one to be denoised) are picked and the class is constructed with a total of \( m \) frames. When distances to the current magnitude frame calculated using the Euclidean distance

\[
d_k = \sqrt{\sum_{i=1}^{m} (b_{k,i} - b_{\text{cur},i})^2}
\]

where \( b_{\text{cur},j} \) and \( b_{k,j} \) are \( i^{\text{th}} \) dimension components of the current and \( k^{\text{th}} \) magnitude frames, and are sorted from smallest to largest, the \( m \) frames with the smallest \( d_k \) are selected into the class member set \( A \). Since \( b_{\text{cur}} \) would have zero distance to itself, it will be assigned index 1 and called \( a_i \) as indicated in Fig. 1.
Noise largely resides in difference components (\(a_{\text{diff}}\)). Therefore, common component (\(a_{\text{com}}\)) is kept and difference component of the current frame is denoised using a denoising algorithm that involves Principal Component Analysis (PCA) [15]. In fact, any denoising algorithm can be effectively used on \(a_{\text{diff}}\) since large portion of the signal energy is still in the common component, which is considered almost noise-free. After denoising \(a_{\text{diff}}\) and obtaining \(\widetilde{a}_{\text{diff}}\), the denoised difference frame, current denoised magnitude frame is reconstructed via \(\tilde{a}_i = a_{\text{com}} + \tilde{a}_{\text{diff}}\). Time domain speech frame is reconstructed by adding phase information and applying inverse FFT.

After applying the described algorithm on each frame, denoised time frames are combined to build the denoised speech data. Since the frames are overlapping, there are several options at the recombining stage. Just adding them onto the appropriate time location is one of them. Here a weighting window can be used to increase the weight of the center of the frame. In our experiments, we noted that just adding the frames (flat window) is sufficient and have least complexity.

It should be noted here that there are several parameters that can be optimized for the best performance on the speech data to be denoised; \(m\) (number of frames in classes), \(n\) (frame size), PCA parameters, recombining options. However, since we intended an algorithm that requires no data dependent optimisation parameters, these optimizations are performed for a large training speech data set and best logical parameter set is kept for all.

**IV. Experiments**

For the experimental work on the proposed algorithm, NOISEUS (Hu, and Loizou, 2007) speech database is used. NOISEUS is composed of 30 English sentences spoken by 3 male and 3 female speakers. Recordings are sampled by 8 kHz 16 bits with approximately 2 seconds in length. 8 different noise type (airport, crowd, car, exhibition hall, restaurant, train station, street and train) are added onto each speech data to obtain 4 SNR levels (0 dB, 5 dB, 10 dB, 15 dB). Noise data is itself taken from AURORA database. In addition, the database is extended by adding 4 levels of white noise onto the data.

Initial experiments are conducted to determine best or reasonable parameter values for CVA. These are; frame size, overlap ratio and neighbourhood size from which the class member candidates are picked. Fig. 2 shows the performance graphics for various frame sizes and input noise levels. From these tests, it is determined that frame size of 40 samples (corresponding to 4 ms) and highest overlap ratio are adequate for both performance and complexity. Neighbourhood size tests, on the other hand, were inconclusive for widths greater than three frame sizes. It is seen that algorithm becomes data dependent for larger search areas. In the following tests, we...
used $N_\text{w} = 3N$ as the neighbourhood size, where $N$ is the frame size in samples.

1. Perceptually motivated subspace algorithm [16], will shortly be called as sub from now on.
2. Psychoacoustically motivated statistical method [17], will be called as stat.
3. Wiener filtering algorithm based on wavelet thresholding multi-taper spectra [18], will be called as wien.
4. A variant of minimum controlled recursive average algorithm [19], will be named as rec.
5. Continuous spectral tracking [20], will be named as spec in the following sections.

Performance measures used in comparisons are Perceptual Evaluation of Speech Quality (PESQ), Log Likelihood Ratio (LLR) and Euclidean Distance in Cepstral Domain (CEP), most used measures in the literature.

| TABLE 1 COMPARISON OF 6 METHODS ON PESQ MEASURE |
|---------------------|-----|-----|-----|-----|-----|-----|
| sub | stat | wien | rec | spec | cva |
| 0 dB | 1.43 | 1.51 | 1.40 | 1.24 | 1.32 | 1.69 |
| 5 dB | 1.87 | 1.68 | 1.84 | 1.77 | 1.82 | 2.05 |
| 10 dB | 2.23 | 2.09 | 2.24 | 2.20 | 2.26 | 2.40 |
| 15 dB | 2.63 | 2.59 | 2.68 | 2.72 | 2.73 | 2.74 |
| 0 dB | 1.37 | 1.20 | 1.34 | 1.13 | 1.34 | 1.64 |
| 5 dB | 1.84 | 1.73 | 1.82 | 1.62 | 1.78 | 2.02 |
| 10 dB | 2.23 | 2.16 | 2.25 | 2.24 | 2.24 | 2.39 |
| 15 dB | 2.63 | 2.60 | 2.65 | 2.69 | 2.70 | 2.74 |
| 0 dB | 1.46 | 1.27 | 1.41 | 1.23 | 1.40 | 1.68 |
| 5 dB | 1.91 | 1.92 | 1.92 | 1.67 | 1.86 | 1.97 |
| 10 dB | 2.24 | 2.25 | 2.25 | 2.17 | 2.28 | 2.34 |
| 15 dB | 2.57 | 2.70 | 2.60 | 2.66 | 2.71 | 2.70 |
| 0 dB | 1.42 | 1.39 | 1.39 | 1.15 | 1.31 | 1.62 |
| 5 dB | 1.91 | 1.89 | 1.89 | 1.68 | 1.85 | 1.98 |
| 10 dB | 2.25 | 2.21 | 2.22 | 2.23 | 2.28 | 2.32 |
| 15 dB | 2.62 | 2.61 | 2.60 | 2.64 | 2.64 | 2.67 |
| 0 dB | 1.37 | 1.42 | 1.42 | 1.23 | 1.26 | 1.70 |
| 5 dB | 1.84 | 1.74 | 1.83 | 1.71 | 1.80 | 2.02 |
| 10 dB | 2.24 | 2.24 | 2.22 | 2.22 | 2.22 | 2.41 |
| 15 dB | 2.60 | 2.57 | 2.64 | 2.67 | 2.63 | 2.72 |
| 0 dB | 1.44 | 1.35 | 1.41 | 1.20 | 1.36 | 1.66 |
| 5 dB | 1.88 | 1.87 | 1.89 | 1.75 | 1.83 | 2.07 |
| 10 dB | 2.24 | 2.25 | 2.27 | 2.24 | 2.31 | 2.38 |
| 15 dB | 2.53 | 2.61 | 2.59 | 2.65 | 2.66 | 2.72 |

1) Perceptual Evaluation of Speech Quality (PESQ)

Standardized by ITU-T P.862 (02/01), PESQ is a commonly used in telecommunication. It is defined as a linear combination

$$PESQ = a_0 + a_1 D_{\text{avg}} + a_2 A_{\text{avg}}$$

(8)
of the average disturbance value $D_{avg}$ and the average asymmetrical disturbance values $A_{avg}$ where $a_0 = 4.5$, $a_1 = -0.01$ and $a_2 = -0.0309$ are the optimized for speech processed through networks [21]. Table I gives the results for CVA along with sub [16], stat [17], wien [18], rec [19], spec [20] in PESQ measure. Best PESQ values are marked with boldfaced characters. Each number in the table is the average of PESQ values for 180 recordings (30 sentences spoken by 6 individuals).

### Table II
**Comparison of Speech Enhancement Methods across Different Environmental Conditions**

<table>
<thead>
<tr>
<th>Environment</th>
<th>Method</th>
<th>0 dB</th>
<th>5 dB</th>
<th>10 dB</th>
<th>15 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crowd</td>
<td>CVA</td>
<td>5.03</td>
<td>4.30</td>
<td>3.86</td>
<td>3.47</td>
</tr>
<tr>
<td>Crowd</td>
<td>Rec</td>
<td>5.12</td>
<td>4.65</td>
<td>4.17</td>
<td>3.73</td>
</tr>
<tr>
<td>Crowd</td>
<td>Spec</td>
<td>4.89</td>
<td>4.40</td>
<td>3.94</td>
<td>3.52</td>
</tr>
<tr>
<td>Crowd</td>
<td>Stat</td>
<td>5.03</td>
<td>4.53</td>
<td>4.06</td>
<td>3.63</td>
</tr>
<tr>
<td>Crowd</td>
<td>Sub</td>
<td>6.59</td>
<td>5.95</td>
<td>5.41</td>
<td>4.92</td>
</tr>
<tr>
<td>Crowd</td>
<td>ELLR</td>
<td>6.78</td>
<td>6.22</td>
<td>5.73</td>
<td>5.25</td>
</tr>
<tr>
<td>Crowd</td>
<td>LLR</td>
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<td>6.40</td>
<td>5.92</td>
<td>5.47</td>
</tr>
<tr>
<td>Crowd</td>
<td>PESQ</td>
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<td>6.52</td>
<td>6.03</td>
<td>5.54</td>
</tr>
</tbody>
</table>

### Table III
**Comparison of 6 Methods on LLR Measure**

<table>
<thead>
<tr>
<th>Method</th>
<th>0 dB</th>
<th>5 dB</th>
<th>10 dB</th>
<th>15 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub</td>
<td>1.19</td>
<td>1.07</td>
<td>0.92</td>
<td>0.70</td>
</tr>
<tr>
<td>Stat</td>
<td>1.10</td>
<td>0.92</td>
<td>0.76</td>
<td>0.62</td>
</tr>
<tr>
<td>Wien</td>
<td>0.86</td>
<td>0.70</td>
<td>0.54</td>
<td>0.50</td>
</tr>
<tr>
<td>Rec</td>
<td>0.66</td>
<td>0.56</td>
<td>0.50</td>
<td>0.46</td>
</tr>
<tr>
<td>Spec</td>
<td>1.35</td>
<td>1.10</td>
<td>0.89</td>
<td>0.73</td>
</tr>
<tr>
<td>CVA</td>
<td>1.11</td>
<td>0.89</td>
<td>0.66</td>
<td>0.50</td>
</tr>
</tbody>
</table>

### Table IV
**Comparison of 6 Methods on CEP Measure**

<table>
<thead>
<tr>
<th>Method</th>
<th>0 dB</th>
<th>5 dB</th>
<th>10 dB</th>
<th>15 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub</td>
<td>0.27</td>
<td>0.25</td>
<td>0.23</td>
<td>0.21</td>
</tr>
<tr>
<td>Stat</td>
<td>0.30</td>
<td>0.28</td>
<td>0.25</td>
<td>0.23</td>
</tr>
<tr>
<td>Wien</td>
<td>0.30</td>
<td>0.28</td>
<td>0.25</td>
<td>0.23</td>
</tr>
<tr>
<td>Rec</td>
<td>0.30</td>
<td>0.28</td>
<td>0.25</td>
<td>0.23</td>
</tr>
<tr>
<td>Spec</td>
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<td>0.25</td>
<td>0.23</td>
</tr>
<tr>
<td>CVA</td>
<td>0.30</td>
<td>0.28</td>
<td>0.25</td>
<td>0.23</td>
</tr>
</tbody>
</table>

2) Log-Likelihood Ratio (LLR)

In LLR, distorted and denoised data are compared statistically [22] and is defined as

$$d_{LLR}(c_s, c_d) = \log \left( \frac{c_s R_c c_d^H}{c_d R_c c_s^H} \right).$$

Here $c_s$ and $c_d$ are Linear Prediction Coefficient (LPC) vectors of the distorted and denoised speech data respectively. $R_c$ is the autocorrelation matrix of the distorted speech signal [23]. Lower LLR values mean higher quality speech signal. In Table II, LLR values for CVA and other 5 methods are compared with boldfaced indicating the best/lowest LLR value for a test input. It is notable that CVA is superior to the compared methods since it generated the lowest LLR for all background noise tests. However, for white noise cases CVA failed to be the best even though the scores are close.

CVA performed best among all methods in all PESQ tests except 5. That indicates about 83% success. In white noise cases, although not the best, CVA performed close to the best.

3) Cepstral Distance Measure (CEP)

CEPT too is based on LPCs and is defined as the distance between LPCs of original and enhanced speech frames as

$$d_{CEP} \left( c_s, c_d \right) = \sqrt{ \sum_{n=1}^{N} \left( c_{s,n} - c_{d,n} \right)^2 } $$

where $N$ is the dimension of LPCs. Lower CEP values indicate higher speech quality [24]. As shown in Table III, proposed CVA method is superior against all other denoising methods for all background noise types and levels applied in tests, except for white noise cases.
V. CONCLUSIONS

Tests conducted on 30 sentences spoken by 6 individuals with added 4 levels of 8 structured background noise recordings (total of 5760 recordings per method per quality measure) let us safely conclude that the proposed CVA method is superior against other 5 methods. In additional tests using white noise, on the other hand, CVA has failed to be the best (total of 720 recordings per method per quality measure). However, in most of the tests that CVA was not the best, its scores were close to the best.

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Integration of Software Defined Radio and Add-on Board into Digital Communication Education with Hands-on Applications

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Abstract—Owing to the theory depend heavily on mathematical models in communication lessons, instructors find students lost in all the equations and notations that given. Setting a lab component for students to put together the theory with practical implementations is not very easy in many times because it may cost a large number of equipment that is not low-priced. Yet there are still some solutions which reduce the cost in designing a real-life communication laboratory and effective in teaching. We present the usage of NI-USRP Software Defined Radio (SDR) and Emona DATEx Add-on Board on digital modulation techniques that take part in communication engineering education. Most commonly used digital modulation techniques; Amplitude Shift Keying (ASK), Phase Shift Keying (PSK) and Frequency Shift Keying (FSK) are analyzed in both devices. Both modulations and demodulations of mentioned techniques are done by experimentally.

Keywords— Software Defined Radio, Communication Engineering Education, Digital Modulation Techniques, USRP, DATEx

I. INTRODUCTION

In general most of the students at communication engineering start learning communication systems with the theory and the principles. However learning the theory and principles solely does not help students to design communication systems properly. They need to acquire experimental skills beside the theoretical domain. In order to bridge this gap instructors use several equipments such as function generators, oscilloscopes, spectrum analyzers that is not affordable many times.

With the development of microprocessors and software technology, traditional equipments began to transform into computer hosted devices which are low-cost, flexible and multi-functional. As an example, SDR, offers large number of tools to teach signals and communications [1]. Limits of traditional equipments, students being remained at the level of pre-digital area and the motivation for SDR based communication education is stated clearly in [2]. SDR refers that analog-to-digital (A/D) conversion is performed at the antenna connector, with all following signal processing (upconversion and/or downconversion, intermediate-frequency (IF) filtering, demodulation, etc.) performed in reconfigurable software using digital signal processing (DSP) techniques [3].

There are several examples of SDR based education courses. Domain analyses such as time, frequency, joint time-frequency, code, and modulation discussed in [4]. M-ary PSK modulation and demodulation implemented in [5]. AM implementation presented in [6]. Five week communication applications programme discussed in [7]. Therefore, multipurpose usage of SDR in communication lessons will be educatory and preliminary for real world.

In this study’s first part we use NI-USRP 2922 supporting frequency range of 400 MHz to 4.4 GHz with SBX daughterboard. It’s omni-directional vertical antenna provides 3 dBi gain for two-way high bandwidth communication. A Gigabit Ethernet connectivity provide data streaming to host processors enables simultaneously sending up to 50 MHz RF signal in and out of the USRP device [8].

Another way of using computer hosted device in communication education is Emona DATEx. By using it students can find the opportunity to experiment the real world signals in lessons.

The Emona DATEx, Digital Analog Telecommunications Experimenter, is an add-on which could serve as a basic training board in various concepts of communication lessons [9]. This add-on is fully integrated with the NI ELVIS II platform and is controllable through the NI LabVIEW development environment. All DATEx knobs and switches are manually controllable or programmable from LabVIEW.

The NI ELVIS II is an all-in-one electronics workstation that performs the functions of instruments which are conventionally found in an electrical engineering laboratory. The NI ELVIS II holds a removable prototyping board on which developers can build electrical circuits which connect the different ELVIS's instruments to achieve a particular experimental goal.

In communication education, examples of DATEx usage limited. Practical aspects of Direct Sequence Spread Spectrum (DSSS) communication discussed in [10]. AM/FM/BPSK signal generating experiments over the internet is presented in [11]. Time and frequency domain demonstrations discussed in [12].
II. ASK MODULATION APPLICATIONS

ASK is a form of amplitude modulation that the amplitude of the carrier wave is shifted proportionally to the amplitude of the digital signal. For a binary message sequence there are two levels; a binary “0” is one amplitude and a binary “1” is another amplitude. We can formulate ASK as:

\[ s(t) = A m(t) \cos(2\pi f_ct) \quad 0 \leq t \leq T \] (1)

where \( A \) is a constant, \( m(t) = 1 \) or \( 0 \), \( f_c \) is the carrier frequency, and \( T \) is the bit duration.

A. ASK Implementation with USRP

USRP Hardware Driver works on a variety of programming languages, operating systems, and development environments such as Linux, Windows, Mac and can be used with numerous frameworks such as GNU Radio, LabVIEW, Simulink, OpenBTS, OSSIE, Redhawk etc. In this study all applications done with LabVIEW because USRP devices that we have supported with licensed LabVIEW Framework.

The basic building block of LabVIEW is the virtual instrument (VI). Each VI consists of a block diagram and a front panel. The block diagram describes the functionality of the VI, while the front panel is a top level interface to the VI. Fig. 1 shows front panel of ASK application.

At the top of the front panel bit stream represents digital data that is randomly produced. At the bottom of the front panel ASK signal is located. While generating ASK signal, all we have to do is to connect the subVIs to each other in an order and feed them with the wires properly. But the theories like Nyquist theorem is crucial while establishing symbol rate values via carrier frequency. Moreover for the getting pure ASK, sampling rate and noise impairment values must be chosen punctiliously. In Fig. 2 block diagram of the ASK application is shown.

B. ASK Implementation with DATEx

In DATEx implementation we use Sequence Generator module for the digital data. 100 kHz master signal is quite appropriate for the carrier frequency because in ideal ASK communication system, we want the carrier frequency to be much higher than the bit rate of the digital data. Generating ASK signal is provided by Dual Analog Switch module. In Fig. 3 modulation (Dotted) and demodulation (Lined) scheme of ASK is shown.

In demodulation part of DATEx implementation for getting an envelope detector, rectifier on the Utilities module and the Tuneable Low Pass Filter (LPF) module is used. Experimental setup with DATEx is shown in Fig. 4.

While selecting the carrier frequency there is not so many options in DATEx. In Master Signals module, signals that can
be used in an implementation are; 100 kHz sine/cosine, 2 kHz sine, 2–8 kHz digital. On the contrary in USRP students can use all the frequencies supported by daughterboard (400 MHz-4.4 GHz).

III. FSK MODULATION APPLICATIONS

FSK refers to a type of frequency modulation that assigns bit values to discrete frequency levels. In other words frequency does not fluctuate over symbol time but fluctuates in discrete amounts in response to message. Amplitude remains unchanged. This is a desirable characteristic for improving the power efficiency of transmitters. In FSK modulated signal consist of two different carriers;

\[ s1(t) = Ac \cos(2\pi f_1 t) \]  
\[ s2(t) = Ac \cos(2\pi f_2 t) \]

One of the signal above is in response to “0” and the other is in response to “1”.

A. FSK Implementation with USRP

LabVIEW interacts with the USRP transmitter by means of four basic functions located on the block diagram’s palette. Transmitter session starts with “Open Tx Session” and goes on with “Configure Signal” used to set parameter values in the USRP. “Write Tx Data” writes the baseband signal to the USRP for transmission and your code should be before this function. Then “Close Session” terminates transmitter operation once the while loop ends. It has five basic functions at the receiver part similarly.

While generating FSK signal, if we rewrite the frequencies as a deviation from the carrier frequency then it is called frequency deviation. This is excursion of the signal above and below the carrier frequency and indicates the quality of signal as it has particular importance in relation to bandwidth.

We can define the bandwidth of a pulse shaping filter that we create in LabVIEW as;

\[ BW = (1 + \alpha) * Rs + 2 * \Delta f \]

where \( Rs \) is symbol rate, \( \Delta f \) is frequency deviation and \( \alpha \) is roll-off factor.

In the receiver part of the application beside the time and frequency domain you can use eye diagram demonstration as in Fig. 5.

Depending the value of modulation index distortion on the received signal can be seen on the eye diagram easily.

As in Fig. 6 by changing symbol rate, alpha, filter type etc. you can easily discover conversions in the modulated signal. After mathematical theory, showing their importance on a real life signal would be very beneficial for students.

B. FSK Implementation with DATEx

For generating FSK signal in DATEx, Voltage Controlled Oscillator (VCO) method is used. The Sequence Generator module is used for modeling the digital data and its SYNC output triggering the scope to provide a stable screen. By using a filter we can distinguish one of the sinewave in FSK and then demodulate it with the help of an envelope detector. For this purpose Tunable LPF module is used in recovering part and then DIODE and RC LPF on the Utilities module is used to form the envelope detector. As in Fig. 7 modulation (Dotted) an demodulation (Lined) scheme of FSK is shown.

Comparator is a useful function for restoring distorted signal. In demodulation part of the application if signal that we recover is not clear we can use comparator function in the Utilities module either.
As seen clearly from the block diagram, setting FSK demodulation is more difficult in LabVIEW than the one in DATEx. As we mentioned before some of the functions used in block diagram are standart while designing real signals. And their connections seems little bit complicated. But it is obvious that USRP gives us chance to radiate our signal in the air and demodulating/recovering a signal with additive noise is not so simple.

### IV. PSK MODULATION APPLICATIONS

In PSK, information is encoded on the phase of the transmitted carrier that changed between two values according to the binary signal level. When encoding bits, the phase shift could be 0 degree for encoding a "0," and 180 degrees for encoding a "1," or the phase shift could be –90 degrees for "0" and +90 degrees for a "1," thus making the representations for "0" and "1" a total of 180 degrees difference. PSK is ideal among FSK and ASK in providing the lowest average power needed for a given bit error rate. A binary PSK signal can be defined by:

\[
s_1(t) = A \cos 2\pi f_c t \quad 0 \leq t \leq T \\
s_2(t) = -A \cos 2\pi f_c t \quad 0 \leq t \leq T
\]  

These two signals have the same frequency and energy but they have a correlation coefficient of 1.

#### A. PSK Implementation with USRP

Our laboratory have two USRP radios, one for transmission and the other one for reception. There are two possible configurations:

- Both radios connected to single computer (running both the transmitter and receiver VIs) with a dual-port Gigabit Ethernet interface, or using a data switch.
- Each radio connected to a different computer; one running the transmitter VI, and the other, the receiver VI.

We preferred the first one for our applications because it is better and faster for managing all the process in one screen. Our experimental set up with USRP can be seen on Fig. 9. Connection between the two USRP is provided with the Multiple Input Multiple Output (MIMO) cable.

#### B. PSK Implementation with DATEx

Switching halves of the PSK signal’s envelopes have the same shape as the message. So PSK generation and the recovery of the data can be handled by conventional Double Side Band Suppressed Carrier (DSBSC) modulation and demodulation techniques. The Sequence Generator module is used for modelling the digital data and its SYNC output triggering the scope to provide a stable screen. With the help of Multiplier module, PSK signal generated as shown in Fig. 11.

By using second Multiplier and Tuneable LPF module we can easily carry out demodulation part of PSK signal.
V. CONCLUSIONS

In this study we propose a new dimension for teaching communication techniques and algorithms by focusing on two computer hosted devices, called USRP and DATEx. ASK, FSK and PSK modulation/demodulation processes presented experimentally. Our approach allows students to concentrate their efforts on real world signals by hands-on applications. Using these devices students will be able to observe signal waveforms, study the effect of noise, design components of a digital communication system. In other words replacing USRP and DATEx with the traditional hardware-only platforms will give students a chance to link the theory with practical implementations.

REFERENCES

Reducing the Effect of In-Band Interference by Using MUSIC Algorithm in Radio Channel Data

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Abstract—In this study Multiple Signal Classification (MUSIC) algorithm were used to reduce the effect of interference in the frequency modulated continuous wave (FMCW) channel data. Since the interference affects a very wide band including the frequency band of interest, the classical band pass filtering did not reduce the noise level. The challenge was to develop an interference reduction algorithm that reduces the noise floor in the frequency band of interest. MUSIC algorithm was chosen for this purpose. The MUSIC algorithm is the one of the subspace method which is frequency estimation technique and it is more useful for reducing the in-band interference than band pass filter.

Keywords— In-band interference, MUSIC algorithm, band pass filter.

I. INTRODUCTION

An in-band interference occurs when a part of transmission band is simultaneously used by another application. Because of interfering signals and desired signal to be transmitted are in the same frequency band, the interfering signals aren’t suppressed in the receiver. The effect of in-band interference in chirp modulated frequency modulated continuous wave (FMCW) data is to raise the noise floor in the average power delay profiles (APDP) [1, 2]. In channel sounding, although the signal processing can be performed off-the-line, measurement campaigns are expensive and difficult to repeat. Since every channel data is valuable for a sound channel model, a technique that alleviates the effect of in-band-interference in FMCW mobile radio channel data is desirable. The basic method proposed to reduce the effect of in-band interference have included clipping the level of interference or put zero to data which has in band interference [1,3,4]. Also Minimum Norm Method (MN) [5] and Prony modelling [6] of data are used to reduce the effect of in-band interference.

Noise subspace methods are used as a frequency detection methods. For example; MUSIC, Pisarenko harmonic decomposition, minimum norm and Eigen Vector (EV) [7]. The methods that based on an eigendecomposition of the autocorrelation matrix into two subspaces, a signal subspace and a noise subspace. In this study MUSIC algorithm was choose to reduce the effect of interference in FMCW channel data.

II. MUSIC METHOD

The MUSIC algorithm is a frequency estimation technique like Pisarenko’s method. In Pisarenko, only a single eigenvector is used and taken to be a set of autoregressive coefficients, whose zeros can be found analytically or with polynomial root finding algorithms. In contrast, MUSIC assumes that several such functions have been added together, so zeros may not be present. Instead there are local minima, which can be located by computationally searching the estimation function for peaks. MUSIC estimates the frequency content of a signal or autocorrelation matrix using an eigenspace method [8].

We assume the received data, \( x(n) \) is a random process consisting of \( p \) complex exponentials in white noise with a variance of \( \sigma^2_w \). \( R_x \) is the \( M \times M \) autocorrelation matrix of \( x(n) \) with \( M>p+1 \). If the eigenvalues of \( R_x \) are arranged in decreasing order (\( \lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_M \)) and if \( v_1, v_2, \ldots, v_M \) are the corresponding eigenvectors, then these eigenvectors can be divided into two groups: the \( p \) signal eigenvectors corresponding to the \( p \) largest eigenvalues, and the \( M-p \) noise eigenvectors that, ideally, have eigenvalues equal to \( \sigma^2_w \).

The white noise variance by averaging the \( M-p \) smallest eigenvalues as follow:

\[
\sigma^2_w = \frac{1}{M-p} \sum_{k=p+1}^{M} \lambda_k
\]  

(1)

The MUSIC method frequency estimation function as follows [7]:

\[
\hat{p}_{MU}(e^{j\omega}) = \frac{1}{\sum_{i=p+1}^{M} |k^H v_i|^2}
\]

(2)
where \( v_i \) are the noise eigenvectors and

\[ e = [1 \ e^{jw} \ e^{j2w} \ ... \ e^{j(M-1)w}]^T \]

is an arbitrary vector.

The locations of the \( p \) largest peaks of the estimation function give the frequency estimates for the \( p \) signal components.

**III. FMCW CHANNEL DATA**

FMCW channel data is used in radio channel measurements. FMCW is used in radar applications and radio channel propagation measurements with success [9]. Measurements were carried out in Manchester city of up to 5 km away in the transmitter and receiver. Bandwidth is 60 MHz. FMCW channel probe device output is in the form of the sum of sinusoids of different frequencies.

Channel data that there is in-band interference free is shown in Fig. 1.a. In-band interference has let to a sudden change in amplitude shown in Fig. 1.b. and it is also seen that the sum of sinusoidal form is disrupted.

FMCW channel data in the time domain shown in Fig. 2. As it seen in Fig. 2 in-band interference has increased an average of the noise floor.

**IV. RESULTS**

Firstly a classical band pass filter is attempted to reduce the in-band interference. As a filter, third-order Butterworth band pass filter is used. Band pass filtering results in a time domain are shown in Fig. 3. It seems that with a band pass filtering the signals are cleaned in the time domain.
Band pass filtering results in a frequency domain are shown in Fig. 4.

As it seen, after the band-pass filtering in a frequency domain, we saw that the crude data noise floor did not decrease. Because when a desired data is taken by band pass filter, interference is also taken.

The reason of appear to have been cleaned signal in a time domain is the suppression of the high frequency component of the signal which is out of the desired band.

After the band pass filter application, the MUSIC algorithm is used to reduce in-band interference. MUSIC algorithm is applied different values of \( p \) and \( M \). The range of appropriate \( p \) values were between 300-330 and \( M \) values were between 400-450. The best result is taken by \( p=320 \) \( M=440 \) and so noise floor is reduced 8 dB approximately with that \( p \) and \( M \) values (e.g. Fig. 5).

V. CONCLUSIONS

The results show that band pass filtering did not work to reduce the in-band interference. Because with a band pass filtering, both signal and interference are taken. But the MUSIC algorithm performed very good in terms of producing a clean spectrum and reduced the noise floor in APDP more than 8 dB effectively.

REFERENCES

Measurement and Evaluation of Electromagnetic Pollution in Samsun City Center Before and After Deployment of 4.5G
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Abstract—There has been a substantial growth in the use of mobile communication services over the last few years. As a result of this growth increase in the number of base stations, and exposed electromagnetic radiation (EMR) levels have become inevitable. Considering the public debate about possible health hazards caused by EMR, in this study, evaluating the effect of establishment of 4.5G systems on existing EMR levels is aimed. For this purpose; the total 536 EMR measurements were conducted in Samsun before and after 1 April 2016 using PMM 8053 EMR meter. It is seen from the measurements that maximum electric field strength ($E_{\text{max}}$) is 6.32 V/m while the maximum average electric field strength ($E_{\text{avg}}$) is 3.26 V/m which are both below the limits (28V/m, 21V/m the minimum values for 100kHz-3GHz band) that are determined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Information and Communication Technologies Authority of Turkey (ICTA). The mean of $E_{\text{max}}$ and $E_{\text{avg}}$ are 1.2111V/m, 0.8892/m before 4.5G, and 1.849V/m, 0.6628 V/m after 4.5G respectively. The results demonstrate that the deployment of 4.5G yielded up to 52.3% increase in $E_{\text{max}}$ while 12.5% in $E_{\text{avg}}$ values. Even though the measured E levels are below the limits; there is a significant increase in them in parallel with 4.5G. It can be also predicted from the measurement results that E levels are likely to increase over forthcoming years, and exceed the lower limits (4 V/m) applied by some countries e.g. Switzerland and Italy.

Keywords—Electric field strength; electromagnetic (EM) measurement; EM pollution; statistical analysis.

I. INTRODUCTION

Electromagnetic (EM) waves are radiated from many sources, both natural and man-made, that produce electromagnetic pollution. In parallel with technological developments, there has been a dramatic growth in the use of cellular systems which based on base stations. Because each base station is an electromagnetic radiation (EMR) source, with the increase in the number of base stations, exposed EMR levels have also increased. Since each base station works within a limited geographical region and for limited number of users, mobile system operators must install more base stations in order to meet growing demand for multimedia services, and communicating from any place. There are around 100,000 base stations in Turkey right now, but with the establishment of 4.5G systems on 1 April 2016, the estimated number of base stations will be around 130,000. Because there is a growing number of base stations being placed into crowded places; measuring, evaluating, the levels of EMR and controlling their compliance with standards/limit values has become more crucial than before. Therefore detrimental effects of EMR on human health have been the subject of many researches [1-9] in the last decade.

There are international standards and limits on effects of EMR on human health. The limits are recommended by an international commission ICNIRP which is recognized by World Health Organization (WHO). The limits of electrical field are shown in Table I based on ICNIRP and ICTA guidelines on exposure limits [10-11].

Table I Reference levels for general public exposure to time-varying electric fields for ICNIRP and ICTA

<table>
<thead>
<tr>
<th>Frequency range (MHz)</th>
<th>Electric field strength (V/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICNIRP</td>
</tr>
<tr>
<td>0.010 – 0.15</td>
<td>87</td>
</tr>
<tr>
<td>0.15 - 1</td>
<td>87</td>
</tr>
<tr>
<td>1 - 10</td>
<td>87/ f¹/²</td>
</tr>
<tr>
<td>10 - 400</td>
<td>28</td>
</tr>
<tr>
<td>400 - 2000</td>
<td>1.375 f¹/²</td>
</tr>
<tr>
<td>2000 - 60000</td>
<td>61</td>
</tr>
</tbody>
</table>

The limits are given for exposure averaged over a six minute interval. Each country has its own determined limits. The USA and some European countries use limits determined by the ICNIRP, while other European countries like Switzerland and Italy use 1/10 of the ICNIRP’s values as a limit. Turkey applies limits that are 75% lower [11] than those suggested by the ICNIRP [10]. There are currently three mobile
communication operators in Turkey and they use 2G (second generation), 3G (third generation) and 4.5G (fourth generation) systems. According to the [11], the limits are 30.9 (V/m) for 900 MHz base station, 43.7 (V/m) for 1800 MHz base station, 45.75 (V/m) for 3G systems, which is 2100 MHz, and also 45.75 (V/m) for 2600MHz base station.

In this study, to evaluate the effects of newly established 4.5G system on EMR levels, extensive EMR measurements were performed before and after 1 April 2016 in Samsun city center, at 67 different locations. Statistical properties of the measured data are determined. The changes in EMR levels which occurred with the deployment of 4.5G systems are visualized through maps.

II. MEASUREMENT OF EM POLLUTION

In order to determine the changes in EMR levels with the deployment of 4.5G, EMR measurements were conducted using PMM 8053 EMR meter, in Samsun city center at 67 different locations considering the number of users, line of sight, distance from a base station. Each measurement location which is separated by a distance of app. 100 meters is shown with red circle in Fig.1.

![Fig.1 Measurement locations in Samsun city center](image)

Total E in the band between 100kHz - 3GHz is measured with PMM–8053 with EP-330 isotropic electric field probe [12] twice in March named as M1, M2 and May 2016, and, named as M3, and M4 respectively. In each measurement, the maximum electric field strength (E_{max}) and average electric field strength (E_{avg}) were recorded. Based on the international standards and ordinances released by ICNIRP and ICTA, the duration of each measurement was six minutes.

III. MEASUREMENT RESULTS

The maximum E (E_{max}) and the average E (E_{avg}) which were measured at 67 different locations are given in Fig. 2.a and Fig. 2.b respectively. Reasons of various E levels may be: the number of base stations in measurement area, output powers of base stations, distances from the base stations, whether there is line of sight (LOS) between the units or not, and the number of users. As seen from the figure that the E_{max} is 6.32 V/m which is measured at 23th location (measurement time 1). The maximum E_{avg} is also obtained at 23th location (measurement time 4) as 3.26 V/m accordingly.

![Fig. 2 a) Maximum (E_{max}) b) Average (E_{avg}) Es versus locations](image)

The statistical properties of measured data are determined and listed in Table II, probability density functions of each measurement are also given in Fig.3. As seen from the Table II that E_{max} varies from 4.49 to 6.32 V/m while E_{avg} varies between 2.78 and 3.26 V/m. Before 4.5G the mean of the E_{max} is 1.2111, it increases to 1.8449 after 4.5G. for the case of E_{avg} corresponding values are 0.5892 and 0.6628 V/m.
### Table II Statistical properties of the measured data

<table>
<thead>
<tr>
<th></th>
<th>$E_{\text{max}}$ (V/m)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>Mean</td>
<td>Std.</td>
</tr>
<tr>
<td>M1</td>
<td>6.32</td>
<td>1.2001</td>
<td>0.9167</td>
</tr>
<tr>
<td>M2</td>
<td>4.49</td>
<td>1.2221</td>
<td>0.8349</td>
</tr>
<tr>
<td>M3</td>
<td>5.59</td>
<td>2.1607</td>
<td>1.2592</td>
</tr>
<tr>
<td>M4</td>
<td>5.11</td>
<td>1.5291</td>
<td>0.9691</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$E_{\text{avg}}$ (V/m)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max.</td>
<td>Mean</td>
<td>Std.</td>
</tr>
<tr>
<td>M1</td>
<td>2.7800</td>
<td>0.5718</td>
<td>0.6488</td>
</tr>
<tr>
<td>M2</td>
<td>3.0600</td>
<td>0.6066</td>
<td>0.6034</td>
</tr>
<tr>
<td>M3</td>
<td>2.8800</td>
<td>0.6940</td>
<td>0.5460</td>
</tr>
<tr>
<td>M4</td>
<td>3.2600</td>
<td>0.6316</td>
<td>0.6263</td>
</tr>
</tbody>
</table>

In order to have better visualization changes in EMR levels are transferred on a map using MapInfo and $E_{\text{max}}$s and $E_{\text{avg}}$s are shown in Fig. 3 and Fig. 4 before and after 4.5G respectively.

![Fig. 3 Probability density function for a) $E_{\text{max}}$, b) $E_{\text{avg}}$](image1)

![Fig. 4 MapInfo picture of $E_{\text{max}}$ for a) before b) after 4.5G](image2)

![Fig. 5 MapInfo picture of $E_{\text{avg}}$ for a) before b) after 4.5G](image3)
IV. CONCLUSIONS

In this study, in order to determine the effect of deployment of 4.5G systems on EMR levels, extensive measurements were performed at 67 different locations in Samsun city centre before and after 1 April 2016. According to 536 measurements the maximum total electric field strength is 6.32 V/m while the maximum average electric field strength is 3.26 V/m. The results demonstrate that the deployment of 4.5G yielded up to 52.3% increase in $E_{\text{max}}$ while 12.5% in $E_{\text{avg}}$ values.

REFERENCES

Monitoring the Signal Strength of Cellular System Operators on a University Campus

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Abstract— In this study, in order to determine the signal strengths of the existing cellular system operators for 2G, 3G and 4G services drive test measurements were conducted on a specific route on Ondokuz Mayıs University (OMU) Kurupelit Campus. The synchronized measurements were performed using nine same brand and model smartphones with “Android” operating system and “Netmonitor” application. It is seen from the measurements that the received signal strength can change depending on the location, frequency, line of sight, and base stations’ output power. 2G signal strengths are significantly higher than 3G/4G. Considering all operators; the signal strengths vary from -51dBm to -87dBm for 2G, while from -51dBm to -103dBm, and from -67dBm to -130dBm for 3G and 4G respectively. The average signal strengths of 2G, 3G and 4G are -65.97dBm, -80.01dBm and -94.52dBm. The quality of signal is higher than the minimum limit (<-100dBm) determined by Information and Communication Technologies Authority (ICTA) of Turkey for 2G at all measurement locations. However, for 3G lower than the limit at 8.33% of all measurement locations for operator C while for 4G 69.71% for operator A. Using these results help to have foresight on needed improvements/enhancements.

Keywords—Cellular System; Signal Strength; Drive Test Measurement; Netmonitor.

I. INTRODUCTION

Communication has an important role in human life, and has been developing each day in parallel with the technological improvements. As a result of these improvements many new generation communication devices have been developed and presented. Mobile communication systems especially mobile phones have become the most common tool of communication over recent years.

In cellular systems, the coverage area is divided into a number of elementary areas called cells, and a base station is placed center of the cell. Each active mobile unit within a cell uses assigned frequencies to communicate with the serving base station. With the movement of mobile user the cell boundaries may be crossed from time to time. In such case new channels are assigned, and call could continue without any interruption. Theoretically each cell is hexagonal; and the design of a cellular system begins with the classification of the coverage area [1-2]. With the growth in the capacity of mobile communications, the size of a cell is becoming smaller and smaller: from macro cell to microcell and to picocell [3-4].

In mobile communication systems, modulated electromagnetic waves arrive at the receiver either Line of Sight (LOS) path or through different paths. Along these paths the transmitted signal undergoes reflection, scattering, diffraction because of the surrounding objects (buildings, mountains, trees etc.), and the received electric field strength varies as a result. This phenomenon is known as multipath fading, and if the receiver position moves the destructive effect of multipath becomes more complicated [5].

In Turkey, currently 2G (second generation), 3G (second generation) and 4G (fourth generation) cellular systems are used, by means of three different Cellular System (CS) operators. In order to maintain customers’ loyalty and gain new customers the CS operators mostly emphasize on “coverage area”, “signal power”, and “signal quality” in commercials. Some recent customer surveys on CS operators show that a high level of satisfaction is strongly correlated with signal strength. Therefore CS operators must improve the provided signal quality in order to meet customers’ demands and fulfill the requirements determined by ICTA. For this reason, in this study, measuring the signal strengths of existing three operators (named as A,B,C) in Turkey for 2G, 3G and 4G systems on a specific route on OMU Kurupelit Campus, transferring them on a map are aimed.

II. MATERIAL AND METHOD

In this study, the signal strengths of 2G, 3G and 4G services of the three CS operators were measured, and the results were transferred on a map. In measurements nine same brand and model smartphones with “Android” operating system and “Netmonitor” application, and nine sim cards whose three are for each CS operator were used. After the determination of measurement route, required mobile network settings were adjusted then Netmonitor application was started. According the type of connection mode measured, the network mode of the each smartphone was adjusted to “2G only”, “3G only”, or “LTE only”. In order to determine the exact measurement locations GPSs’ of all phones were turned on. Drive test measurements were conducted the busiest times of a day, at a speed of 30km/h, during 25min. with 5sec. intervals. The signal quality of each operator was measured in terms of dBm.

Fig.1 shows an image for a measurement conducted with Netmonitor application. Netmonitor application which is an
Android based network software, shows the information of connected base station, signal strength, and location instantly, and save these in CLF (list) as well as KML (map) format. Fig.2 a and b illustrate examples of screen shots of 2G and 3G measurements at a measurement location respectively. In figure, Operator shows the connected CS operator’s MCC-MNC number and name, Type represents the connection type, LAC defines the connected cell number while CID indicates connected sector number. RNC also indicates radio network controller.

![Fig. 1. Netmonitor application and its operation](image)

![Fig.2. Examples of Netmonitor measurements for a) 2G, b) 3G](image)

According to communique [6-7] released by Information and Communication Technologies Authority of Turkey coverage area related signal strengths of CS operators were determined. In accordance with this communique minimum signal level for coverage obligation to the operators will be -104 dBm for GSM 900, -102 dBm for GSM 1800 and -104 dBm for the networks using both GSM 900 and GSM 1800. Beside this, the classification can be made according to Table I.

<table>
<thead>
<tr>
<th>dBm equivalent</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>-101 or less</td>
<td>Very weak</td>
</tr>
<tr>
<td>-100…-91</td>
<td>weak</td>
</tr>
<tr>
<td>-91…-81</td>
<td>average</td>
</tr>
<tr>
<td>-80 or more</td>
<td>Good</td>
</tr>
</tbody>
</table>

### III. RESULTS

Drive test measurements that performed for 2G, 3G and 4G systems using Netmonitor are given in Fig.3.a, b, c for the operators A, B, C respectively. As seen from the figure that 2G signal strengths are significantly higher than those for 3G and 4G. It is seen from the 2G measurements that neither very weak nor weak signals concurred, and the operator C has worst signal strength. The main reason of this case may be; the change in the signal strength inversely proportional to frequency (Friis transmission equation [5]), and using 1800 MHz for 2G while the others use 900 MHz. It is also seen from the measurements that the received signal strength can change depending on the location, frequency, line of sight, and base stations’ output power for all operators.

The overall assessments for the measurements are given in Table II. As seen from the Table that the average signal strengths of 2G are -63.36 dBm for operator A, while 64.88dBm and -69.69dBm for operator B and C respectively. Corresponding signal strengths of 3G are measured as -85.27dBm, -76.67dBm and -78.33dBm. As a result of newly establishment of 4G; very weak signals are recorded at many location whose averages are -104.21dBm, -89.55dBm, and -89.80dBm for the operators A, B and C respectively.

<table>
<thead>
<tr>
<th>System</th>
<th>Operator</th>
<th>Signal strength (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max.</td>
</tr>
<tr>
<td>2G</td>
<td>A</td>
<td>-51</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>-51</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>-57</td>
</tr>
<tr>
<td>3G</td>
<td>A</td>
<td>-63</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>-51</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>-59</td>
</tr>
<tr>
<td>4G</td>
<td>A</td>
<td>-74</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>-67</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>-78</td>
</tr>
</tbody>
</table>
In order to point out each measurement location’s signal strength KML files are saved during drive test measurements. Then these files are used to display geographic locations and corresponding signal strengths in dBm. The obtained images are given in Fig. 4, Fig. 5, and Fig. 6. for 2G, 3G and 4G services of operators A, B, C respectively.

Fig. 3. Signal strengths change for the operators a) A b) B c) C.

Fig. 4. Netmonitor measurement results of operator A for a) 2G, b) 3G, c) 4G.
Fig. 5. Netmonitor measurement results of operator B for a) 2G, b) 3G, c) 4G

Fig. 6. Netmonitor measurement results of operator C for a) 2G, b) 3G, c) 4G
IV. CONCLUSIONS

In this study, the signal strengths of existing three operators (named as A, B, C) in Turkey for 2G, 3G and 4G systems on a specific route on OMU Kurupelit Campus are measured and transferred on a map. It is seen from the measurements that 2G signal strengths are significantly higher than those for 3G/4G. Because of being established on 01/04/2016 4G signal strengths are inadequate. Beside this, the received signal strength can change depending on the location, frequency, line of sight, and base stations’ output power. With the use of the measurement results and/or the maps the lower/higher signal strength locations, and the regions required enhancement, and the operators to improve their signal quality can be determined for 2G/3G/4G systems.

REFERENCES

The State and Momentum Equations of a New Type Five Phase Segmental Switched Reluctance Motor

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Abstract—In this study, the mathematical equations of five phase segmental switched reluctance motor (SARM) was established by using basic electrical motor model. This five phases SARM has a different rotor and excitation structure than classical ARM, and its phase currents and magnetic field variations with respect to inductance were calculated by means of magnetic equivalence circuit. The value of inductances was calculated by stating the visible inductance profiles of different phases instantaneously in order to emphasise the difference between two motors. In addition, the momentum equation of SARM was obtained by determining the situations of different phases. The inductance values were calculated by assuming the current applied to phases created from an ideal current source and by determining the situations of different phases. It was revealed that the SARM produced much more momentum than the classical ARM having the same phase number by using a mathematical model.

As a result of this study, it was understood that the magnetic flow equations depend not only on the function of rotor position, but also the changing current

Keywords—Switched Reluctance Motor, Mathematical Model, State Equation

I. INTRODUCTION

Switched reluctance motors (SRM) are electrical machines with simple structure but superior properties which converts electrical energy into mechanical energy with changing reluctance effect changes and which are in need of convertor power electronics while performing this action. Although SRMs first put forward in the 1800s, the driving motor depending on developments in power electronics in the early 1960s has become possible. Although it is the engine type based on the old, the examination and investigation of these engines are new. In particular, the studies on this motor are seen to be focused after 1980 [1] [2] [3].

ARMs are increasingly being used in changing-rate and servo-type industrial applications due to mechanical structures and low rotor losses [4]. These motors have many different application areas such as electric cars, spacecraft, household appliances, radars, automatic door systems and water pumps.

The most important characteristic of SRM’s is having magnetic circuit in non-linear form depending on phase circuit and rotor position. That’s why SRM’s need a strong controller in order to produce maximum torque [5].

The difference of new 5-phase bipolar excitation SARM from classic SRM is that the rotor structure has been altered completely and contains variations in excitation method. In case of being used of the same resource, flux distributions produced by the winding of both engines per phase and torque amounts produced depending on this show changes due to inductances of the windings and the mutual inductance value occurs between phases [6]–[7].

Besides the successful results obtained in motor structure and performance of classic switched reluctance, in also the studies on switched reluctance motors (SARM) based on segmental and two-phase energizing essence forming the basis of this study important progresses have been made. In order to model the non-linear structure of SARM and in case of the installation of motor, different structure were suggested by many researchers in motor and actuator circuit design in order to eliminate the fluctuations in the current varying due to time. The first study about this subject was conducted by Lawsonson and Agu in literature in 1964 [8]. Meerow et al. examined the performances of SARM’s with various polarity and winding structure [9]. Uygun et al. performed the analysis of linear model of magnetic circuit by designing U-type segmental type SRM [10]. Belhandi and Koli showed the comparative simulation results of speed and torque parameters of the classic SRM and SARM by using the finite element method [11]. In other studies, the flux distribution topologies of SARM was developed on magnetic structure by changing pole, rotor and winding structures and engine driver optimizations were arranged.

In this study, a control algorithm including PI control for a new segmental switched reluctance motor with bipolar excitation, 5 phases and 10/8 pole configuration, which was designed as segmental rotor (SARM), and entered in the literature has been developed and presented.

Also in this study, the actuator circuit including PI control option developed for controlling bipolar driven segmental rotor and computer-controlled management, monitoring interface will be discussed.
II. STRUCTURAL FEATURES OF BIPOLAR EXCITED SEGMENTAL ROTOR 5-PHASE AND 10/8 SWITCHED RELUCTANCE MOTOR

In this section, it has been mentioned briefly the structural features of the new design segmental type of engine belonging to SARM.

In Fig. 1. (a), newly designed bipolar excited segmental type SRM using short flux paths and the cross sectional view of 5-phase classical switched reluctance motor with 10/8 configuration to be used in performance comparisons were given. The case that occurs in case of being energized of this phase is shown in Fig. 2 (b).

The new developments obtained in newly designed switched reluctance motor having 5 phases and 10/8 stator/rotor configuration which is detailed in Fig. 2. can be summarized as follows. 10/8 SRM has a different rotor structure from conventional SRM. The rotor consists of both the packages created from siliceous plates and an aluminum block where these packages are placed in. as well as the package that was created from a block of aluminum and silicon steel consists of the placement of the package. The reasons of using the aluminum block is the limiting feature of magnetic field that comes out and is being a very light metal compared to other metals (e.g., stainless steel, etc.) [6].

Thus, torque value produced per Nm/kg weight taken into account in the engines, Nm / kg will be automatically increased. In the engine, the two-phase energizing method was used instead of the single phase energization method used in a conventional SRM. The reason for using such a method is to see that the magnetic poles of the engine follow the short flux paths when the windings are properly installed and simultaneously two phases of SARM is energized. This case (reduction of flux path) will lead the reduction in both sheet losses and the temperature of motor sheets.

As it can be understood in Fig. 2 (b), segmental SRM operates by using short current paths instead of long flow paths unlike conventional SRM. Since in every time, two phases remain with power, it is clear that common inductance occurred between the phases and this case will create complexity for the finding of non-linear models of the engine.

III. STATUS EQUITIES OF SARM

In order to be comprehended better of the running of machines like engine and generator, it is required to be prepared mathematical models with the aim of realizing simulation and experimental studies. In this section, running of the new design 5-phase segmental switched reluctance engine, mathematical model belonging to the driver is taken as a basis by using basic motor equities [5].

While the design is being performed, it is stressed on the assumptions that the flux produced by any of the phases in different polarity passes through air range, the circuit is completed briefly; leak flux status is ignored; stator and rotor steel magnetic permeance is accepted as infinite and when stator and rotor poles are overlapped, it is maximum.

In Fig. 3, magnetic equivalent circuit belonging to 5-phase SARM has been given.

In Fig. 3, magnetic equivalent circuit belonging to 5-phase engine is given. Here, $e$ represents opposite electromotor power, $\Phi$ represents flux, $G$ represents magnetic permeability of phases and $U_p$ represents voltage drop. By using this
magnetic equivalence and basic electric machines, the following processes have been realized.

According to ARM basic knowledge, when angular change is considered, it is possible to write the equivalent moment expression for the moment produced by the engine depending on the co-energy produced by the motor as seen in Fig. 1:

\[ T(\theta, i) = -\frac{dW_c(\theta,i)}{d\theta} \quad (\lambda = \text{Sabit}) \]  

(1)

If the moment produced by SARM is calculated from general moment energy by using Equation 1, the following is obtained;

\[ T = \frac{1}{2} \left( \frac{dI_a}{d\theta} V_a + \frac{dI_b}{d\theta} V_b + \frac{dI_c}{d\theta} V_c + \frac{dI_d}{d\theta} V_d + \frac{dI_e}{d\theta} V_e \right) + i_{1a} \frac{dM_a}{d\theta} + i_{1b} \frac{dM_b}{d\theta} + i_{1c} \frac{dM_c}{d\theta} + i_{1d} \frac{dM_d}{d\theta} + i_{1e} \frac{dM_e}{d\theta} \]

(2)

Here, \( T \) represents the produced moment (Nm), \( L \) represents overlapped location phase inductance (mH), \( \theta \) represents rotor location angle (degree), \( M \) represents common inductance (mH), \( i \) phase flow (amper). The following equation can be written according to Kirşof’s flux rule:

\[ \phi_a + \phi_b + \phi_c + \phi_d + \phi_e = 0 \]

(3)

\( \phi_x \) (as being \( x=a, b, c, d, e \)) represents phase fluxes. Depending on magnetic conductivity, flux change belonging to each phase depending on conductivity (as being \( \phi_x(a, b, c, d, e) \)) is expressed as in Equation 4:

\[ \phi_x = G_x(\theta)u_x \]

(4)

Here, the thing expressed is \( G_x(\theta) \) (as being \( x=a, b, c, d, e \)) represents magnetic permeability of phases while \( u_x \) (as being \( x=a, b, c, d, e \)) is representing voltage drop. Besides, the values of the sources are calculated as in Equation 6:

\[ e_x = Ni_x \]

(5)

\( e_x \) (as being \( x=a, b, c, d, e \)) represents the value of the source, \( N \) represents the wrapping number belonging to each phase and \( i_x \) (as being \( x=a, b, c, d, e \)) represents flow belonging to each phase. If it is considered as the value of \( u \) potential;

\[ u_x = e_x - u_p \]

(6)

is obtained. With the widened expression, phase fluxes can be calculated as in the Equation 7.

\[ \phi_x = G_x(\theta)\left(e_x - u_p\right) \]

(7)

Flux connections belonging to each phase can be expressed as follows;

\[ \lambda = N\phi_i \]

If it is used for the Equation 4 flux connection, it is written as follows;

\[ \lambda_a + \lambda_b + \lambda_c + \lambda_d + \lambda_e = 0 \]

(9)

If the magnetic permeability of the phases is expressed as a function of phase inductances, (as being \( x=a, b, c, d, e \)), it is obtained as follows;

\[ G_x = \frac{L_x}{N^2} \]

(10)

When flux connections are widened depending on this expression (as being \( x=a, b, c, d, e \)), it becomes;

\[ \lambda_x = L_x(\theta)\left(e_x - u_p\right) \]

(11)

An arbitrary flow is described as \( i_p = \frac{u_p}{N} \) (as being \( x=a, b, c, d, e \));

\[ \lambda_x = L_x(\theta)(i_x - i_p) \]

(12)

is obtained. If this equity obtained is places in the Equation 9, it becomes;

\[ L_x(\theta)(i_a - i_p) + L_x(\theta)(i_b - i_p) + L_x(\theta)(i_c - i_p) + L_x(\theta)(i_d - i_p) + L_x(\theta)(i_e - i_p) = 0 \]

(13)

If the value of \( i_p \) is taken from this equity, it is obtained as follows;

\[ i_p = \frac{L_x(\theta)\phi_a + L_x(\theta)\phi_b + L_x(\theta)\phi_c + L_x(\theta)\phi_d + L_x(\theta)\phi_e}{L_x(\theta) + L_x(\theta) + L_x(\theta) + L_x(\theta) + L_x(\theta)} \]

(14)

If the Equation 10 is rearranged according to Equation 12, Equation 15 is obtained for phase \( \lambda \):

\[ \lambda = \left(L_x(\theta)\frac{L_x^2(\theta)}{L_x(\theta) + L_x(\theta) + L_x(\theta) + L_x(\theta) + L_x(\theta)}\right)i_p \]

(15)
This expression can be written as the same for the other phases. As it is easily understood from the expression, core inductance value belonging to phase A is seen as follows;

\[
L_{aw} = L_a(\theta) - \frac{L_a^2(\theta)}{L_a(\theta) + L_b(\theta) + L_c(\theta) + L_d(\theta) + L_e(\theta)}
\]  

(16)

Similarly, common inductance values are found between phases A and B as;

\[
M_{ab} = -\frac{L_a(\theta)L_b(\theta)}{L_a(\theta) + L_b(\theta) + L_c(\theta) + L_d(\theta) + L_e(\theta)}
\]

(17)

A. Visible Inductance Profile of SARM

In order to be comprehended of running of the Segmental ARM more clearly, it is required to examine visible inductance profiles. In this method, thinking that the phases of segmental ARM are run with ideal flow source and by revealing the status of different phases at each moment, the values of inductances will be calculated. In this calculation method, phase switches were ignored and phases were connected as star like in Fig. 4.

At any running moment of the designed engine, the phases given in Table I will run together. Accordingly, if only B and C phases are thought to be energized at the first sight, the circuit in Fig. 5 will be obtained.

| A Phase | 0 | + | 0 | 0 | - |
| B Phase | 0 | 0 | - | 0 | + |
| C Phase | - | 0 | + | 0 | 0 |
| D Phase | + | 0 | 0 | - | 0 |
| E Phase | 0 | - | 0 | + | 0 |

At any running moment of the designed engine, the phases given in Table I will run together. Accordingly, if only B and C phases are thought to be energized at the first sight, the circuit in Fig. 5 will be obtained.
\[ i_b = -i_c \]
\[ i_a = 0 \]
\[ i_d = 0 \]
\[ i_e = 0 \]

If flux connections are written for this energizing status again, it is written as;
\[ \lambda_b = \left( \frac{L_b^2(\theta)}{L_a(\theta)+L_b(\theta)+L_c(\theta)+L_d(\theta)+L_e(\theta)} \right) + \frac{L_c^2(\theta)}{L_a(\theta)+L_b(\theta)+L_c(\theta)+L_d(\theta)+L_e(\theta)} i_b \]  \hspace{1cm} (18)

\[ \lambda_c = \left( \frac{L_b(\theta)+L_c(\theta)}{L_a(\theta)+L_b(\theta)+L_c(\theta)+L_d(\theta)+L_e(\theta)} - \frac{L_c^2(\theta)}{L_a(\theta)+L_b(\theta)+L_c(\theta)+L_d(\theta)+L_e(\theta)} \right) i_b \]  \hspace{1cm} (19)

Since the value of the flux flowing from A phase to B phase through the airgap is \( \lambda_{ab} = \lambda_a - \lambda_b \), if Equations 19 and 20 are rearranged, the following is obtained;
\[ \lambda_{bc} = \left( \frac{L_b(\theta)+L_c(\theta)}{L_a(\theta)+L_b(\theta)+L_c(\theta)+L_d(\theta)+L_e(\theta)} - \frac{L_b^2(\theta)+L_c^2(\theta)}{2L_a(\theta)L_b(\theta)+L_c(\theta)+L_d(\theta)+L_e(\theta)} \right) i_b \]  \hspace{1cm} (20)

By using the flux expression expressed above, “visible” inductance value called as \( L_{bc} \) can be calculated by using \( L = \lambda/i \) equity. This value is the common inductance equity between; b and c phases;
\[ L_{bc} = L_a(\theta)+L_c(\theta)-\frac{L_b^2(\theta)+L_c^2(\theta)}{2L_a(\theta)L_b(\theta)+L_c(\theta)+L_d(\theta)+L_e(\theta)} \]  \hspace{1cm} (21)

B. Produced Moment Equitity in SARM

Similarly, if it is thought that only B and C phases are energized and \( i_b = -i_c \) status is considered, moment expression takes these values for both phases [6];
\[ T = \frac{1}{2} \left( \frac{dL_{nb}}{d\theta} i_b^2 + \frac{dL_{nc}}{d\theta} i_c^2 \right) + i_b i_c \frac{dM_{bc}}{d\theta} \]  \hspace{1cm} (22)

\[ T_{bc} = \frac{1}{2} \left( \frac{dL_{nb}}{d\theta} i_b^2 + \frac{dL_{nc}}{d\theta} i_c^2 \right) - i_b i_c \frac{dM_{bc}}{d\theta} \]  \hspace{1cm} (23)

If visible inductance that has been given for B and C phases is used;
\[ L_{bc}(\theta) = L_{nb}(\theta) + L_{nc}(\theta) - 2M_{bc}(\theta) \]  \hspace{1cm} (24)

is obtained. Moment value obtained with this equivalent inductance is as follows:
\[ T_{bc} = \frac{1}{2} \left( \frac{dL_{nb}}{d\theta} i_b^2 \right) \]  \hspace{1cm} (25)

\[ T_{bc} = \frac{1}{2} \left( \frac{dL_{nb}}{d\theta} i_b^2 + \frac{dL_{nc}}{d\theta} i_c^2 \right) - i_b i_c \frac{dM_{bc}}{d\theta} \]  \hspace{1cm} (26)

IV. CONCLUSIONS

In this study, by considering the running conditions of five-phase segmental type switched reluctance engine (SARM) and using basic electrical engines model, status equities have been obtained.

Popularizing the engine structure of the complexity of SARM and comprehending its difference compared to classical ARM, visible inductance profiles of the system have been examined. Considering that the phases of new type SARM is run by ideal flow source and the status of the different phases at each moment, inductance values have been calculated. It has been explained that the engine designed through models produces more moment than classical switched reluctance engine having the same phase number.

Phase flows of this new five-phase SARM having a rotor and stimulation structure different from classical ARM and magnetic flux changes in the type of inductances have been found by using magnetic equivalent circuit.

In order to be understood of this difference more clearly, by revealing common inductance profiles and the status of...
different phases at each moment inductance values have been calculated. Finally, moment production of the engine has been obtained by using the inductance equity

REFERENCES
Lean Six Sigma Applying to Reduce the Maintenance Time in Power Plants

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Abstract— This paper aimed to illustrate the use of the Lean Six Sigma (LSS) methodology in power plants maintenance. LSS has become the indeed method for process performance improvement in many industrial companies and LSS has been gradually increasing its acceptance in electric power generating that confronts challenges, such as, how to decrease maintenance time, increase quality, better use resources etc. Consequently, the quality of any process may be enhanced by utilizing Lean Six Sigma in any climate and it has the potential to offer a useful approach in term of improving quality and reducing costs. Lean Six Sigma is an exclusive method that helps identify possible improvement areas. The study includes the plant maintenance cycle time from request writing to work finished. Improvement opportunities were identified from a high-level value road map. The Define, Measure, Analyses, Improve and Control (DMAIC) approach was applied to a treat the identified opportunities for improvement. The result shows that the maintenance time was reduced from 180 days to 95 days.

Keywords— Lean Six Sigma, maintenance Time, DMAIC, CTQs, DPMO

I. INTRODUCTION

We are sense the huge development of the maintenance programs. It is leading to mend raising power plant reliability and assuring plant capacity by applied the deferent maintenance kinds. The LSS methodology was firstly developed and implemented by Motorola in 1985[1, 2].

Motorola knew that there was a modality of betterment which would be classification to the five phases of problems treatment applied by manufacturers, i.e., DMAIC. DMAIC is the mainly five steps for every maintenance planners of the power plant.

Leant Six Sigma is a controlled, depends on the data methodology used to remove and minify the practices hence the job faults and squandering (time and sources) [3].

To obtain Six Sigma goodness and practices of a job must be no more than 3.4 defect per million opportunities (DPBO). The researchers submit new ways to monitor data and analyse to appear (DPMO). Six Sigma essential offer amount is that rules for maintenance practices improvement, statistical process, alertness in the work, and maintenance management framework central on high-return improvement power plant generation result in persistent improvement and considerable economic earning [4]. When the power plants applied the Six Sigma, it can discover the factors affect on the maintenance in power plant operation, recognize the optimal scale of allowance and betterment chances. In this paper, the DMAIC practices of the Lean Six Sigma was going ahead to obtain goodness and generation improvement in power plants. The studying of LSS and practice it gives us more opportunities to improvement the equipment operation. These opportunities to be noticed for everything for improvement and confirm the requirement for study driving to improvement and placing methodologies that like LSS [5]. Now the question is when deciding the maintenance procedure when the lean six sigma start? And lean six sigma application starts. All the current studies are leading to when power plants want to minimize these equipment's maintenance time and cost, it must apply the lean six sigma methodology. In the lean six sigma methodology waste is a very important factor affect on the maintenance process of improvement equipment operation [6].

II. SIX SIGMA STEPS (DMAIC)

to improve and increase the quality the maintenance practices to obtain a high level of power plant operation, must arrive at the standard specification by using six sigma (Define, Measure, Analyses, Improve, Control) as shown in Fig. 1. These steps are[7, 8]:

1) Define: First of all, the problem should be defined and requirements of the customers need to be identified. This step is set the guesses to development the maintenance requirements and concentrate on the applications of six sigma methodology but not forget the customer demands.

2) Measure: This step is illustrating the errors in maintenance applications and schedules the information to use it to confirm the improvement targets.

3) Analysis: this step is important in every program to minimize the errors, and studying the information collected and put it in tables. And in next period set the targets and planning to reach the wanted level.

4) Improvement: in this step planners confirm the changes in the maintenance practices and measured it's affecting on the equipment quality (CTQ), and find acceptable rules to minimize change errors and measure affecting on (CTQ) to find the best solutions.

5) Control: this is the final step of six sigma applications, in it the planners find the advantages of applied six sigma and schedule the results of the practices.
Today Six Sigma methodology applied widespread in the world such us (engineering, markets, industrial, management). Particularly, the widespread applications of Six Sigma were possible because organizations were able to articulate the benefits of Six Sigma presented.

III. LEAN

Lean is a process improvement methodology, used to deliver products and services better, faster time and at a lower cost. Womack and Jones (1996) defined lean as “a way to specify a value, line up value-creating actions in the best sequence, conduct those activities without interruption whenever someone requests them and perform them more and more effectively. In short, lean thinking is lean because it provides a way to do more and more with less and less—less human effort, less human equipment, less time, and less space—while coming closer and closer to providing customers with exactly what they want”.[9]

IV. LEAN SIX SIGMA

Lean tools focus on improving maintenance flows and standardizing work processes. To improve the flowing maintenance and job operation by concentrate the lean methods. The classics saw to the lean six sigma is depend on decrease the waste and the losses time in the maintenance operation and the spender money in this operation, and finished maintenance work in the set time. The six sigma methodology sight have the measurement to decrease errors in the operation changes and confirm it's in maintenance works quality and spenders. Lean six sigma is represents the strong sets to increase the speed maintenance works and decrease the waste to obtain the better solution of maintenance engineering management [3].

V. CASE STUDY

In this paper, we will apply the lean six sigma methodology to decrease the maintenance request time. Our work executed in Baiji thermal power plant in Iraq through practice lean six sigma steps from taking the maintenance requests during one year (2012) and the requests rate about 180 day. The purpose of maintenance requests in the power stations is too useful to confirm the maintenance efficiency and productivity. Essentially the request helps maintenance technical to obtain vital power plant data and set every equipment work. The request avoids an incompatible utilization of oral statement. The principles of request system aimed to make a regular shape for data collected and work to equipment rehabilitation.

For this work, we suggest integrated methodology of lean six sigma. In first we must put the road map for this study to define the opportunities amendment and progressing it to the maximum level. And we must fix all the changes in the road map without pay attention to defects type. Six sigma methodologies must apply in this process on these chances. Six sigma methodologies is a strategic way to keep the maintenance on the right road. In this paper, we can use lean six sigma methodology practice or one of them depending on the errors type[10].

VI. DMAIC STEPS

1) Step 1: Define. The critical execution variables of request cycle time were defined. Furthermore, it was determined implementation of every related specification related to all the reasons and confirmed. This means that criticizes the quality of the properties (CTA) of the agreed it was well known as well as the expected performance of their point of view. We are all the reasons we have identified through the process of mapping and data collection that we had more than tripled sessions. Each “bone” appears a group's effect on the troubles, parallel expectations. And to go too far to find the root cause we have implemented a statistical control process parallel to expect. As illustrated in Fig. 2 [5, 6].

We find the major reason of troubles. We showing in the figure the mechanical process (rehabilitation, soldering, water treatment, lubrication and planners state) a huge difference. Then we continued studying each variable by statistical and supposition tools.

![Pareto chart of maintainance days](image-url)
2) Step 2: Measure. Each CTQ’s of measurable enable us to confirm work basis. In this step, to confirm the maintenance requirements we must collect the information around the happened process in the maintenance wait and anticipation and ultimately valiantly the measurement by using modern technical to measure and detect the errors such as Pareto chart.

3) Step 3: Analyze. The concentrate in an analysis for the practice holes in every procedure in CTQs, the intention in this steps dividing the defects to "do it, not do it ". We seek for the style of lean behavior also the style of best behavior in power plant maintenance. Such must in this style the hard work continued on effort confirm and navigable. As well, we take all the input and output variation between the input and output of CTQs. moreover, we tighten to concentrate to some subjects and find an appropriate mechanism for data analysis. Also, we found the different reasons of the troubles. When using the method of statistical analysis at this stage, depending on the type of items will wait a few days.

4) Step 4: Improve. If we wish to examine closely a strong improvement in the process must underestimate the ability gaps in CTQ steps. Also, we support every supposition of cause root to the errors and confirm the substitution solutions and in a parallel way obtain the better solution. Work on these securities began based on the data obtained in 2012.

The recommendations, as described below:

- Resettlement the planners and managers offices to maintenance location in power plants.
- Identify the people responsible for managing the stores that contain maintenance materials.
- Give adequate space for planners to management raw Material.
- Writing a periodic report to the requests of maintenance in order to be classified.
- Prevent acts of direct equipment maintenance without a request order.
- Continuous work development courses for planners to work in order to stay within the set in plans.
- Emergency notices that are written by the operations shift leader.

5) Step 5: Control. We desire to control the better setting of each better solution. The behaviors of all the CTQs able do steady over time to a normal nonrandom low point in maintenance troubles concentrating. Furthermore, we have to assure the reformative process are taken and moving the control of the hot process to the maintenance holder. We are also in parallel using special techniques to maintain the performance of maintenance and monitoring work, this is done by scheduling maintenance requests that require more than 3 months in key process indicator (KPI) and submit them to the maintenance manager. Furthermore, for the next study the reformative process are scheduled. It is controlled maintenance works and monitor the progress of work by the maintenance departments chiefs and submit periodic reports on the progress of business to the maintenance head manager in the power plant.

VII. RESULTS

These papers focus on the major faults in the mechanical, electrical and other taking into account the resulting acts of disparate maintenance process to get the desired results of the right request planning procedure. This work and collect data started in 2012; after 6 months showed signs of success by %50 as we see in Fig. 3. As in Fig. 3, we were able to reduce the average time required for maintenance from 180 days to 105! Furthermore, we have improved the response to urgent requests for maintenance at the station and overcome the difficulties related in terms of adjusted a time for maintenance, as it is shown in fig 4. Follow-up development and success of our work to develop a system to identify actions that need further scientific studies.

VIII. CONCLUSION

Lean Six Sigma is not an enchantment solution that you can use for quick success. It is a methodology, which has to be slowly integrated into the culture of the organization. It can be applied to any process and we as Maintenance Plants need to make the best out of this methodology.

(Seri 1 the requests life Improvement.)

![Fig. 3 Improvement in the requests life](image)

![Fig. 4 a. Improvement on emergency request in2009](image)
Fig. 4 b. Improvement on emergency request in 2010

Fig. 4 c. Improvement on emergency request in 2011

Fig. 4 d. Improvement on emergency request in 2012

REFERENCES


Analysis and Design of an Axial-Flux Coreless Permanent Magnet Synchronous Generator with Single Stators and Double Rotors

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Abstract—In this study, permanent magnet axial-flux coreless synchronous generator is designed as single stators and double rotors and its electromagnetic and structural characteristics are analyzed. Core is not used in the stator of the machine intended to be designed. Aim of this study is to provide reduction of iron loss. Moreover, easiness in the production stage of the machine is provided. Three-dimensioned electromagnetic analysis of the designed machine has been done through finite element method and transient solutions are suggested based on this. Within this study, arrangements have been made depending on certain standards in order that permanent magnets and coils obtain direct alternating current. The designed new axial-flux generator move as permanent speed of 500 rpm and so maximum voltage of approximately 100 V per phase is obtained. Furthermore, this machine does not need a gear system due to its design structure.

Keywords—Axial-flux generator, Permanent magnet, Generator, Single stator, Double rotor

I. INTRODUCTION

Electrical machines have started to be used almost within all areas nowadays. Every passing day, new studies take place in literature. New models are developed in these studies done. Within these developed models, increases in power density of the machine, change in the shape of design as well as size reductions and studies done depending on excitation types have gained speed. Studies have centred on axial-flux permanent magnet machines as different excitation types recently. Permanent magnet axial machines have been aimed to be analyzed due to reasons such as being highly efficient and economic and having ability to produce energy at low cost [1]. Micro wind turbine application has been conducted in a study by Pop et al. Here it has been found that after a comparison of axial and radial-flux permanent magnet generator, axial-flux permanent magnet has shown the best result. It has been discovered that axial-flux generator is less costly [2]. Reducing no-load momentum of the generator has been possible using skewed magnets in axial-flux permanent magnet [3]. It is a huge advantage that axial flux permanent magnet generator (AFPMG) has high efficiency, compact size and light weight compared to other applications. Main purpose of this type of machine design is to obtain the best of output power [4]. Furthermore, axial-flux permanent magnet generator with coreless stator is considered as machines having high power density for energy-generating systems [5].

What has been aimed to reveal within this study is that iron losses have reduced using coreless stator. Moreover, the machine has been made lighter. As core has not been used in the stator windings of the designed machine with coreless stator, stator iron losses have been eliminated completely. As there has not been use of the core in the stator, stator windings will not be influenced by core warm-ups. As the surfaces of the windings are in contact with air, it will be able to take the heat on the surface out more quickly. As the core is not used for the stator windings in this type of axial machine, production difficulty to arise from applications in such type of machines has been reduced. Though copper losses have increased here as the core has not been used in the stator, this newly designed machine provides production convenience. This design can be used to obtain alternating current without need for gear system during wind turbine applications. Besides, it is intended to be used in electric vehicles both as in-wheel motor and generator. Finite element method has been used for analysis in this study. Finite element method is a numerical method used in solving linear and nonlinear partial differential equation [6]. Design features of the designed machine have been given within the second chapter. The third chapter consists of electromagnetic analysis results of the machine. Consequences related to simulation depending on time have been given within the fourth chapter. The final chapter includes the conclusion.

II. THE DESIGN FEATURES OF THE MACHINE

Main purpose of the machine design is to obtain the best of output power. Estimated value of the output power belonging to the designed machine can be calculated using the equality below;
In order that output power of the machine reaches maximum, rate between its dimensions should be as in \( k_d = \frac{1}{\sqrt{3}} \) [7]. Statement related to the relationship between the dimension and power in axial flux permanent magnet synchronous generator has been given within equality 1 [8]. The \( k_p \) here is electric wave form factor and calculated as 0.5 in sinusoidal designs where \( k_i \) is current wave form and calculated as \( \sqrt{2} \) for sinusoidal wave forms [9]. \( B_g \) refers to maximum flux density within the air gap. \( P \) refers to dipole number and \( f \) refers to the frequency. \( D_o \) and \( D_i \) refers to inner and outer diameter respectively where \( R_d \) refers to the ratio of the inner diameter to the outer diameter. The designed axial-flux coreless permanent magnet synchronous generator is given in Figure 1. There are one coreless stators and two rotors within this design.

There exist two rotor discs in Figure 1. 12 permanent magnets have been placed into the single end of the lower and upper rotor discs. The stator winding has been placed between two rotor discs. The stator winding consists of 9 coils in total. Each phase in windings corresponds to three coils.

Rotor steel used for the machine has been made up of M19. There are 12 magnets in rotor steel. Magnets placed upon the rotors have been placed between each other with 30 degrees each. Do and Di values are 145 mm and 85 mm.

Geometric structure of the magnets is as shown in Figure 3. These types of designed magnets are more advantageous to prevent the heat and more suitable to obtain a straight sinusoidal wave. Permanent magnet used in axial flux permanent generator is Neodymium. Length of the neodymium magnet is 50mm and its thickness is 8mm. Representation of flux paths of the magnets have been given in Figure 4.
Generator stator designed within this study has a coreless structure. For the rotor core, steel which is of M-19 class and frequently used in electric machines. The steel used for core is not a linear material. While making solution, the analysis program applied makes solution using B-H curve. B-H curve of M19 steel is shown in Figure 5.

![Fig. 5 B-H curve of M19 core material.](image)

24 trapezoidal permanent magnets (NdFeB) and 9 coreless coils in total have been used in the machine shown in Figure 1. 12 magnets have been placed into the single end of the two rotors for each. There an air gap of 1mm between the magnets placed upon the stator and rotor. Average magnetic flux density is approximately 0.68 Tesla. As a consequence of all these parameters, power estimated according to equality 1 is approximately 770 W.

### III. ELECTROMAGNETIC PROPERTIES OF THE MACHINE

Distribution of magnetic flux density for 3D model is given in Figure 6. Flux density values formed around the magnet have been given. Flux density in windings and steels has been measured as 0.8-0.9 Tesla.

![Fig. 6 Distribution of magnetic flux density for axial flux permanent magnet generator.](image)

Direction of the flux path within the arrangement of the magnets is shown in Figure 7. Arrangements of the permanent magnets here are in the form of N-S-N-S and S-N-S-N. Accordingly, while flux path of the dual magnet group on z plane is mostly up, flux path of the permanent magnet group both at its right and left is the opposite. For a clearer appearance of the flux path, it had been shown in Figure 5 without steel and permanent stator.

![Fig. 7 Appearance of magnetic flux path for axial flux permanent magnet generator.](image)

### IV. THE SIMULATION RESULTS FOR THE MACHINE

Current and voltage values according to the simulation results of the new designed machine have been given below. They have been given according to the angular velocity at 500 rpm of the machine.
Within the Fig. above, coils belonging to each phase and their relationships with each other have been given. There are three coils per phase for each stator winding here. 3 coils in total have been used for each phase. Resistance has been determined as 1.72 ohm in total for one phase of stator. The permanent magnets used are trapezoidal, phase voltage and current wave form to be obtained time-dependently have been demonstrated in Figure 10, 11 respectively.

![Fig. 10 Voltage value for A-B-C phase of axial-flux permanent magnet generator.](image)

![Fig. 11. Current value for A-B-C phase of axial-flux permanent magnet generator](image)

It is observed that within the simulations results the output signal is in the form of alternating current. One of the advantages of the new designed machine is that generated wave form is at quite a good level. Data to be obtained at speed of 500 rpm, roughly 100V voltage and roughly 5A current are in Figure 10, 11 respectively.

V. CONCLUSION

Aim of this study is to analyze the structurally different and alternating-current generating axial-flux coreless permanent magnet synchronous generator design through the finite element method and to present its performance. Application of axial-flux coreless permanent magnet synchronous generator with two rotors and single stators has been given. Within this study, due to the form of design there will be much convenience in production. Though the designed machine is coreless, a high power density has been obtained. That the output wave forms are close to sinusoidal reveals that design data related to the machine have been properly chosen. 9 coils and 24 magnets have been used in the machine and according to the simulation results at 500 rpm, the machine generates approximately 750 W power. The designed generator within this study offers a solution for both in-wheel motor-generator in electric vehicles and wind power applications.

REFERENCES

Direct Digital Frequency Synthesizer Designs in MATLAB

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Abstract—This study presents the structure of the Direct Digital Frequency Synthesizers (DDFSs) which have several advantages compared to conventional synthesizers such as high frequency, fast switching speed and low power dissipations. In order to lessen the physical area and power dissipation, ROM compression techniques are applied in designs. Bipartite Table Method (BTM) and Multipartite Table Method (MTM) are utilized in this study because of the fact that they provide high compression rates. By using MTM, the compression rates of 157.54:1, 726.71:1 and 3463.29:1 are obtained at 58.40 dB, 75.30 dB and 84.66 dB SFDR levels, respectively.

Keywords—DDFS, CORDIC, MTM, BTM.

I. INTRODUCTION

Direct Digital Frequency Synthesis is one of the most popular techniques to synthesize frequency for the systems requiring specific frequencies, fast switching, low power dissipation and small silicon area. There are several methods using table based or iterative approaches to implement Direct Digital Frequency Synthesizers (DDFSs). In addition to natural advantages of the approaches, ROM compression techniques are applied to reduce the ROM size. Furthermore, the approaches are enhanced with some modifications offering trade-off between Spurious Free Dynamic Range (SFDR), switching speed and the used silicon area.

Direct Digital Frequency Synthesizers (DDFSs) are commonly used in several areas such as defense industry, satellite systems, radars, test and measuring equipments, etc. As distinct from analog or indirect synthesizers, DDFSs provide high frequency resolution, fast switching speed, continuous phase switching, small physical area and low power dissipation [1]. For the last 10 years, works on the frequency synthesizers are focused on minimizing the used area and power dissipation while keeping the spectral purity above an acceptable level [2], [3] and [4]. High frequency synthesizers are also studied with some recently offered approaches [5], [6] and [7].

A DDFS consists of three sub blocks which are phase accumulator, phase to amplitude converter and the digital to analog converter. Fig. 1 illustrates the principle parts of a DDFS.

Fig. 1 Principal parts of DDFS

A. Phase Accumulator

Phase accumulator is used in DDFS for an adjustable frequency output. It is controlled by an N bit Frequency Tuning Word (FTW). Several frequencies can be obtained by using this digital control word with one clock source.

Phase accumulator works as an N bit counter and a digital phase wheel is created. Each of the $2^N$ points on this wheel correspond the amplitude value of the related phase. The increment of the counter is determined by the FTW. Fig. 2 illustrates the digital phase wheel idea.

Fig. 2 Digital Phase Wheel [1]

The frequency of the output signal is

$$f_{out} = FTW \times \frac{f_{ref}}{2^N} \quad (1.1)$$

The frequency of the output signal is
B. Phase to Amplitude Converter (PAC)

There are two main approaches for phase to amplitude conversion in a DDFS. The corresponding amplitude value of the related phase can be obtained by using Look Up Tables (LUTs) or iterative calculations. While table based methods allow operating at higher frequencies, iterative methods provide better spectral purity. Many studies have done about both methods for the last decade [2, 9], [11] and [12]. The works about table based methods have generally aimed to reduce the ROM size and to increase the Spurious Free Dynamic Range (SFDR) which shows the spectral purity of the generated sinusoid. On the other hand, COnordinate Rotational Digital Computer (CORDIC) based iterative methods have been proposed to achieve better SFDR levels.

C. Digital to Analog Converter (DAC)

DACs are used to convert the digital data taken from the PACs to analog signals. DAC part is one of the most important parts of the DDFS and directly related to its performance.

The resolution and sampling frequency of DAC are able to determine the limits of DDFS. While delta-sigma and R-2R type DACs are beneficial when high resolution is required, current steering type DACs have sampling rates up to GSPSs with comparatively lower resolution. The lower resolution comes with higher quantizing errors and this cause a decrement in SFDR but oversampling may lessen the decrement a little. Addition to all these, the AC and DC characteristics of the DAC are also important and need to be considered at the implementation stage [8].

II. METHODS

A. CORDIC Based DDFSs

CORDIC is a structure that was proposed by Volder to calculate basic trigonometric functions in 1959 [10]. In CORDIC based algorithms, two-dimension vector rotation idea is used. The vector rotation idea is shown in Fig. 3, and the related trigonometric equations are

\[ x_0 = x_1 \cos \theta - y_1 \sin \theta \]  
\[ y_0 = x_1 \sin \theta + y_1 \cos \theta \]  
\[ \frac{x_0}{y_0} = G [\tan \theta \frac{1}{1}] \frac{x_i}{y_i} \]  

As mentioned earlier, CORDIC is applied as an iterative method to calculate some trigonometric functions. Angle (\( \theta \)) of rotation is completed after \( T \) sub rotations and evaluated as in Eq. (2.4) where \( \delta_i \) is the direction of the rotation.

\[ \theta = \delta_0 \theta_0 + \delta_1 \theta_1 + \cdots + \delta_t \theta_t \]  
\[ \delta_k \epsilon \{-1,0,1\} \]  

\[ \tan \theta \] is chosen as multiple of \( 2^{-1} \) so that (2.3) is easily applied digitally. The equation can be rearranged as

\[ x_{i+1} = x_i - y_i \delta_i 2^{-i} \]  
\[ y_{i+1} = y_i - x_i \delta_i 2^{-i} \]

The gain constant is generally applied as the initial end point. \( P(G, 0) \) is used instead of \( P(0, 0) \) as the initial end point of the vector where \( G = \prod_{i=1}^{T} \frac{1}{\sqrt{1+2^{-i}}} \) [11].

B. Table Based DDFSs

Table based methods originally have a simpler idea. ROMs/RAMs are used as LUTs. Phase accumulator is utilized as the address counter of the ROMs.

The ROM size determines the resolution of the DDFS. The bigger the ROM size is, the better the resolution is. This was the bottleneck of the traditional table based methods. The bigger ROM size causes much more power dissipation and needs more physical area. ROM compression techniques have been enhanced to overcome this problem. Quadrant compression, Sunderland and Hutchinson methods, Bipartite Table Method (BTM) and Multipartite Table Method (MTM) are some of the most common ROM compression techniques.

Quadrant compression technique uses the symmetric structure of the sinusoid. Instead of a LUT that stores the sine values between \( 0 \) and \( 2\pi \), a LUT that stores the sine values between \( 0 \) and \( \pi/2 \) is used. The most significant two bits of the \( P \) bit phase word determine the quadrant of the phase wheel and the rest include the phase information. The block diagram of the technique is given in Fig. 4.

BTM was proposed by Dinechin and Tisserand in 2005 [4]. The technique depends on partial piecewise linear approach. The \( x \) axis is divided into \( 2^n \) equal pieces and \( f(x) \) is
interpolated separately for each. The equations of the slope and approximated $f(x)$ are

$$m_i = \frac{f(x_{i+1}) - f(x_i)}{x_{i+1} - x_i} \quad (2.7)$$

$$f_{app}(x) = y_i + m_i(x - x_i) \quad (2.8)$$

As distinct from the piecewise linear approach, $x$ axis is divided into $2^b$ larger intervals ($b < a$) and same slope value used for the adjacent pieces in larger intervals. Thus, the ROM size is efficiently decreased. Fig. 5 shows the piecewise linear approach used in BTM.

![Fig. 5 Bipartite Table Method (BTM) [4]](image)

In BTM, there are two tables to store the values required for the interpolation. The $y_i$ values are stored in Table of Initial Values (TIV) with $a$ bits and Table of Offsets (TO) stores information for $m_i$ and $(x - x_i)$ part of Eq. (2.8) with $\beta$ and $\gamma$ bits separately. The ROM is addressed by $2^a + 2^{\beta + \gamma}$ bits [9].

The linearity of $m_i \times (x - x_i)$ provides opportunity to make the ROM size smaller. By using this linearity property (2.10), it can be beneficial to use more than one TO for some SFDR levels. When the number of TOs is more than one, the technique is called Multipartite Table Method (MTM).

$$m_i \times (x - x_i) = m_i x_1 + m_i x_2 + \cdots + m_i x_k \quad (2.9)$$

The study of De Caro and his friends shows that the number of TOs is not proportional to SFDR. The study also indicates that SFDR of the DDFS strongly depends on $x, y, z$ numbers. From the point of this view, it is obvious that an optimization is essential to get best results. If the number of TOs is more than two then the optimization requires more complex algorithms and calculations. Moreover, the higher number of TOs does not ensure smaller physical area in compression with two or three TOs for the SFDR levels less than 90 dBc [9]. Thus, this paper is focused on the table based methods with one or two TOs.

### III. MATLAB RESULTS

There are three main objectives while designing a DDFS. These are maximizing the SFDR, minimizing the ROM size and increasing the maximum operating frequency as much as possible. In this paper, the SFDR and ROM size considerations are investigated.

#### A. BTM Design

As mentioned earlier, BTM uses two different tables to store the sine amplitude information. While one of them is for initial values, the other one is for the offset values. The size of TIV is calculated as

$$TIV_{size} = R \times 2^a \quad (3.1)$$

where $R$ is the amplitude resolution and $a$ is the number of bits that represents $TIV$ values. TO values are represented with $\beta + \gamma$ bits and the size is calculated as

$$TO_{size} = (R - a) \times 2^{\beta + \gamma - 1} \quad (3.2)$$

The sum of $TO_{size}$ and $TIV_{size}$ gives the total ROM size. The compression ratio is evaluated as

$$compression \ rate = \frac{R \times (a + \beta + \gamma)}{TIV_{size} + TO_{size}} \quad (3.3)$$

The $P$ phase information taken from the accumulator includes $\alpha$ and $\gamma$ bits. The ROM size depends on these bits with some $\beta$ bits in $\alpha$ bits. Fig. 6 shows the decomposition of the phase word.

![Fig. 6 Phase Word Decomposition in BTM Design](image)

#### TABLE I

<table>
<thead>
<tr>
<th>$\alpha$</th>
<th>$\beta + \gamma$</th>
<th>Resolution (bits)</th>
<th>SFDR (dB)</th>
<th>ROM size (bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2</td>
<td>8</td>
<td>56.22</td>
<td>352</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>8</td>
<td>58.14</td>
<td>448</td>
</tr>
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<td>5</td>
<td>4</td>
<td>8</td>
<td>56.25</td>
<td>640</td>
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<tr>
<td>5</td>
<td>2</td>
<td>10</td>
<td>70.45</td>
<td>960</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>10</td>
<td>69.93</td>
<td>1600</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>10</td>
<td>71.80</td>
<td>2880</td>
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<td>5</td>
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<td>12</td>
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<td>12</td>
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</tr>
<tr>
<td>5</td>
<td>4</td>
<td>12</td>
<td>80.88</td>
<td>14720</td>
</tr>
</tbody>
</table>

This paper is focused on the table based methods with one or two TOs.
The BTM design results are given in Table I and allow two significant deductions. Firstly, it is obvious that increasing the length of the phase word does not improve the SFDR and it makes the ROM size bigger. So, determining the best decomposition of the phase word has a great importance. Secondly, increasing the amplitude resolution provides better SFDR but causes a notable increment in the ROM size.

**B. MTM Design**

MTM is originally based on BTM and requires smaller ROM size comparing to it with a negligible decrease in SFDR. It is generally preferred when higher SFDR is required because BTM provides the same SFDR with a very high ROM size. In this part of the paper, some MTM design results are investigated and are compared with BTM.

The TIV size calculation in MTM is similar to BTM. Using more than one TO makes the difference in total ROM size. The phase word decomposition is given in Fig. 7 where $\theta_i = \beta_i + \gamma_i$.

![Fig. 7 Phase Word Decomposition in MTM Design](image)

**Total ROM size in MTM is calculated as**

$$Total\_size = TIV\_size + \sum_i^n TO_{i\_size}$$ \hspace{1cm} (3.4)

where $n$ is the number of TOs and (3.5) is used to evaluate $TO_{i\_size}$.

$$TO_i = [(R - \sum_{k=0}^{i-1} \gamma_k) \times 2^{\beta_{i+1}+\gamma_{i+1}} - 1]$$ \hspace{1cm} (3.5)

The phase word length and the amplitude resolution determine SFDR and ROM size. Some design results are given in Table II. As clearly seen from the table it is possible to reach better SFDR by just rearranging the decomposition of the phase word. The results indicate that minimizing a value allows making total ROM size smaller. It is also clear that increasing $P$ and $R$ values causes a remarkable rise in SFDR.

While closer $\alpha$, $\beta_1$ and $\beta_{i+1}$ values provide the best compression, it is more complicated to offer any condition for the best SFDR. Although there are some algorithms proposed to find out the best decomposition of the phase word for a specific SFDR level, there is not any multi-objective algorithm to optimize both the SFDR and the ROM size. In this paper, any algorithm is not used and the results given in tables show the effect of the parameters.

**Table III shows some design results with different $P$ and $R$ values at SFDR levels around 57, 75 and 84 dB. It demonstrates that increasing the number of TOs is more beneficial at higher SFDR levels. Although the table shows that increasing the number of TOs in all SFDR levels gives better results in ROM size, it is not practical. De Caro and his friends show that the more TO is the better ROM compression ratio but not the smaller required area for DDFS. Table III also indicates that it is not possible to get a remarkable increase in SFDR without increasing $P$ and $R$ values.**

<table>
<thead>
<tr>
<th>Techniques</th>
<th>SFDR (dB)</th>
<th>ROM size (bits)</th>
<th>Comp. Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>BTM</td>
<td>57.32</td>
<td>1040</td>
<td>31.51:1</td>
</tr>
<tr>
<td>BTM (2 TOs)</td>
<td>57.09</td>
<td>304</td>
<td>107.79:1</td>
</tr>
<tr>
<td>BTM (3 TOs)</td>
<td>58.40</td>
<td>208</td>
<td>157.54:1</td>
</tr>
<tr>
<td>BTM</td>
<td>75.31</td>
<td>3008</td>
<td>119.83:1</td>
</tr>
<tr>
<td>BTM (2 TOs)</td>
<td>75.20</td>
<td>928</td>
<td>388.41:1</td>
</tr>
<tr>
<td>BTM (3 TOs)</td>
<td>75.30</td>
<td>496</td>
<td>726.71:1</td>
</tr>
<tr>
<td>BTM</td>
<td>84.24</td>
<td>16384</td>
<td>208:1</td>
</tr>
<tr>
<td>BTM (2 TOs)</td>
<td>84.50</td>
<td>1984</td>
<td>1717.68:1</td>
</tr>
<tr>
<td>BTM (3 TOs)</td>
<td>84.66</td>
<td>984</td>
<td>3463.29:1</td>
</tr>
</tbody>
</table>

**IV. CONCLUSIONS**

The DDFS structure has been investigated in this study. The phase accumulator, phase to amplitude converter and digital to analog converter blocks of the structure has been mentioned in section I. Later on, CORDIC, BTM and MTM
based DDFS have been explained in section II. In section III, table based methods have been focused and some MATLAB design results have been interpreted. BTM designs are revealed with two different $R$ values. $59.26$ dB SFDR level is achieved with $R=8$ and $272$ bits ROM size. Increasing the resolution to $11$ bits, $81.98$ dB SFDR level is reached with $1056$ bits. $157.54:1$, $726.71:1$ and $3463.29:1$ compression rates are obtained at $58.40$ dB, $75.30$ dB and $84.66$ dB SFDR levels respectively by increasing the number of TOs.

The main problem of the table based methods is that they need much more physical area. When advanced ROM compression techniques such as MTM are applied to minimize the area, a complex optimization algorithm is required at higher SFDR levels. There are some beneficial optimization techniques such as MTM are applied to minimize the area, a complex optimization algorithm is required at higher SFDR levels. There are some beneficial optimization techniques such as MTM are applied to minimize the area, a complex optimization algorithm is required at higher SFDR levels but multi-objective optimization techniques may be considered as a future work to optimize the sampling frequency, ROM size and SFDR.

REFERENCES

MEASUREMENTS OF HIGH FREQUENCY ELECTROMAGNETIC WAVES IN CENTER OF MUS

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Abstract— All electrically powered devices cause electromagnetic wave exposure on human body and we use them nearly every moment in a day. Mobile phones, computers, televisions, hair dryers, lighting systems, etc. they all use electricity and naturally radiate electromagnetic waves. Effects of electromagnetic waves are not clear but international organizations define limit values depending on epidemiological studies in this field. In this study we measure high frequency electromagnetic waves in city center of Mus. Measurements are made at mobile phone frequencies and results compared with limit values. All measurement techniques and limit values are appropriate with Information and Communication Technologies Authority (ICTA) standards. Measurement points are selected according to population density in city center.

Keywords— Include at least 5 keywords or phrases

I. INTRODUCTION

Electromagnetic waves were created by motion of electric charges. They have two main component; electric field and magnetic field. Electric field values are generally shown in volt per meter unit and magnetic field values generally shown in Tesla unit.[1]

Communication systems often use electromagnetic waves for data transfer. Each frequency band of electromagnetic spectrum has its own specification and characteristic.[2]

As it shown in Fig. 1 communication systems use radio-frequency band of electromagnetic spectrum. Their frequency is less than 300 GHz. Mobile phones, satellites, radar systems, wireless modems, TV and radio broadcasts use radio-frequency band of electromagnetic spectrum. [3]

Fig. 1 Electromagnetic Spectrum[7]
All electrically powered devices radiate electromagnetic waves. Additionally, some communication devices use electromagnetic waves for their purpose and increases electromagnetic waves they were radiated.

World Health Organization (WHO) researches effects of electromagnetic waves in last three decades. There are a lot of studies about health effect of electromagnetic waves. But most of them could not show health effect of electromagnetic waves clearly. International Commission on Non-Ionizing Radiation Protection (ICNIRP) determines limit values for non-ionizing electromagnetic waves. In Table I, ICNIRP limit values are shown.[4-5]

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>E-Field Strength (V.m⁻¹)</th>
<th>H-Field Strength (A.m⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1 Hz</td>
<td>-</td>
<td>3.2 x 10⁻³</td>
</tr>
<tr>
<td>1-8 Hz</td>
<td>10000</td>
<td>3.2 x 10⁻²/f</td>
</tr>
<tr>
<td>8-25 Hz</td>
<td>10000</td>
<td>4000/f</td>
</tr>
<tr>
<td>25 Hz-3 kHz</td>
<td>250/f</td>
<td>5</td>
</tr>
<tr>
<td>3-150 kHz</td>
<td>87</td>
<td>5</td>
</tr>
<tr>
<td>0.15-1 MHz</td>
<td>87</td>
<td>0.73/f</td>
</tr>
<tr>
<td>1-10 MHz</td>
<td>87/0.5</td>
<td>0.73/f</td>
</tr>
<tr>
<td>10-400 MHz</td>
<td>28</td>
<td>0.073</td>
</tr>
<tr>
<td>400-2000 MHz</td>
<td>1.375/0.5</td>
<td>0.0037/0.5</td>
</tr>
<tr>
<td>2-300 GHz</td>
<td>61</td>
<td>0.16</td>
</tr>
</tbody>
</table>

In Table I, f values indicates frequency values. Limit values of electric field for mobile phone frequencies are more than 40 volts per meter. In Turkey this value is 9.15 volts per meter, so Turkey applies more than four times lowered limit values on non-ionizing radiation protection.[4]

II. MATERIALS AND METHODS

In this paper we measured electric field of mobile phone frequencies (GSM900, GSM1800, UMTS, LTE) in city center of Mus. Measurements are made in main streets of the city. With GPS data we showed measurement results on the map.

A. Measurement Device and Probe

We used Wavecontrol SMP2 electromagnetic radiation measurement device. Device specifications are shown below:

1) **1 Hz to 18 GHz Broadband Measurements**: With RMS and Field probes can measure up to 18 GHz.
2) **Spectrum Analysis**: With a specific probe, spectrum analysis 1 Hz to 400 kHz.
3) **Weighted Peak Method (WPM)**: Real time comparison in percentage with selected limits.
4) **Assessments According to European Directive 2013/35/EU**: In accordance with international standards such as ICNIRP, IEC, EN, IEEE, etc.
5) **GPS Support**: GPS module integrated in the instrument.
6) **Connection Options**: USB and Fibre Optic connection supported by a PC software.

As measurement probe we used WPT mobile frequency probe. This probe measures only total electric field value of 2G, 3G and 4G frequencies. Measurement device and probe are shown in Fig. 2.

B. Measurement Mode and Standards

Measurements are made in mobile measurement type. Measurement device was put on a car and while car was travelling 30 km/h fixed speed, device measured electric field of the medium. Measurement instances are taken in every 5 seconds.

Measurement results were shown on a map according to GPS data and field strength.

III. MEASUREMENT RESULTS

According to measurement results;
- Maximum measurement value is 5.85 V/m and measured in middle of the Ataturk Boulevard.
- Average measurement value is 1.098 V/m during the whole measurement
- Comparison of electric field strength values in main streets from the highest to the lowest: Ataturk Boulevard, Istasyon Street and Cumhuriyet Street.

Measurement results are shown in Fig. 3. Green points show 0-2 V/m electric field strength value. Yellow points show 0-2 V/m electric field strength value.
show 2-4 V/m electric field strength value and Red points show 4-6 V/m electric field strength value.

**Fig. 3** Electric Field Strength Measurement Results in Mus City Center

**IV. CONCLUSIONS**

All measurement values are under the limit values of International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Information and Communication Technologies Authority (ICTA) but some epidemiological shows that electric field values we measured could be dangerous for human being, especially for the children. In countries like Italy and Switzerland limit values for mobile frequencies in some regions are 2 V/m. Especially red points in the map can be dangerous for livings.[6]

Lowering output power of some base stations or moving base stations to less dangerous places in the city center can be a solution for high electric field values.

**REFERENCES**


Simulink Model for Piece Wise Linear Approximation of Memristor

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Abstract— Memristor is a passive circuit element which firstly presented to science world by Leon Chua in 1971. Chua showed a missing link among four fundamental circuit variables which generate basic passive circuit elements. Chua described this missing link between charge and flux, named it as memristor. Memristor is firstly realized by Stanley Williams and his team from HP (Hewlett Packard) research laboratories in 2006. In this study, doped and undoped TiO$_2$ are sandwiched between two Pt layers in nano scale. And this element demonstrated voltage-current characteristic like memristor. Physically implementation of memristor is announced with a paper to science world in 2008. The studies about memristor have quite increased along with this study. In this paper, a new PWL (Piece Wise Linear) memristor model is obtained thereby linearizing current-voltage characteristic of memristor. The equivalent circuit is derived from this model, built in Simulink and results are observed. The results are compared with other studies in literature and obtained results have been shared.

Keywords— Control Equations, Equivalent Circuit, Memristor, PWL Model, Simulink Model

I. INTRODUCTION

Memristor is a semiconductor passive circuit element which is firstly proposed to science world by nonlinear circuit theorist Leon Chua in 1971 [1]. Fundamental passive circuit elements defined by four fundamental circuit variables: voltage, current, charge and flux. For instance; resistor is derived from relationship between voltage and current, capacitor is derived from relationship between voltage and charge and inductor is derived from relationship between current and flux. Chua noticed that there is a missing link between charge and flux. And defined this missing link as “$M = \frac{d\phi}{dq}$” and named it “memristor”. Passive circuit elements and definitions of these elements from fundamental circuit variables are shown in Fig.1.

As the name memristor consists of a combination of the words memory and resistor. Theoretically, this element will protect last electrical quantities such as voltage or current even if energy cuts off on it. Therefore, memristor shows memory characteristic. Memristor also has resistor characteristic due to its definition equation which shown in (1). When this equation derived from type of voltage and current, equation (2) is obtained. This equation is a kind of charge dependent resistor like Ohm’s Law. Memristor characterized by “memristance” as shown (1) and has electrical unit “ohm”.

$$M(q) = \frac{d\phi}{dq} \quad (1)$$

$$M(q(t)) = \frac{V(t)}{i(t)} \quad (2)$$

Voltage-current (V-I) characteristic of memristor has a hysteresis curve. In this characteristic, memristance value of memristor changes between high and low resistance values according to applied
voltage. I-V characteristic of memristor is shown in Fig.2. Memristor is also a frequency dependent circuit element which was mentioned before in Chua’s paper [2]. And Chua gave frequency dependent I-V characteristic of memristor in this paper which is shown in Fig.3. According to this figure, when applied frequency is increased, hysteresis curve of characteristic narrows. And when frequency goes to infinity, I-V characteristic becomes linear as resistor characteristic.

In 2008, 37 years after the definition of memristor, Stanley Williams and his team from HP (Hewlett-Packard) announced that the memristor is physically implemented [3]. The team used TiO$_2$ which is a semiconductor material in this study. Pure TiO$_2$ has high resistance and doped TiO$_2$ with oxygen vacancies has lower resistance. These two kinds of TiO$_2$ sandwiched between two Pt layers and so element is obtained. Fig.4 shows HP memristor model. In this model, there is a thin film between pure and doped sides. Position of this film changes depending on energy flows from where. When energy flows from doped side to pure side, memristance value decreases. Otherwise, when energy flows from pure side to doped side, memristance value increases. These changes consist of depending on ion mobility. So, HP memristor model also called as linear ion drift model.

After physically implementation of memristor, interest in memristor is increased dramatically. Studies about memristor have been accelerated by modelling memristor and using these models in various circuits [4]-[12]. Modelling of the memristor could also be a milestone for applications that cannot be done before because of the lack of available circuit elements and for new circuit applications which previously unthinkable but could be considered with existence of memristor.

In this paper, one of the memristor model PWL (Piece Wise Linear) memristor model design will be made using the model in Simulink. I-V characteristic and M-V characteristic of proposed memristor model will be shared. And also these results will be compared with other studies which described in literature. Suggestions and new future studies about memristor and proposed model will be written in conclusion part.
II. METHODOLOGY

A. PWL (Piece Wise Linear) Memristor Model

Linear ion drift model [3], nonlinear ion drift model [4], [5] and Simmons tunnel barrier model [4], [5] are memristor models which are in nano size. PWL model is different from them is a model which depend on I-V characteristic of memristor [12]. The goal of this model, linearization of I-V characteristic of memristor and so obtain new equivalent circuit models for memristor and using this circuit models in memristor based circuit applications and future circuit applications. PWL memristor model is shown in Fig.5.

![Fig.5 PWL memristor model](image)

B. Proposed PWL (Piece Wise Linear) Memristor Model

In this paper, a different PWL memristor model is proposed. Current-voltage characteristic and memristor-voltage characteristic of the proposed model are compared with existing publications in the literature. Proposed PWL memristor model is shown in Fig.6.

![Fig.6 Proposed memristor model in simulink](image)

In Fig.6, memristor model consists of signal generator block, derivative block, embedded matlab function block, to workspace blocks and scopes. Generator block generates sinus signal which has \(v(t)=3.999\times\sin(2\pi t)\) value. Derivative of signal is taken by derivative block. Commands that consist of control equations for operating model are written in embedded matlab function block. The operation of this block as follows: Generated signal and derivative signal which is generated by derivative block are input parameters of embedded matlab function. Processed signals in this block are obtained as output current and memristance. These current and memristance values are transferred to workspace by “to workspace” block. In workspace, current-voltage and memristance-voltage characteristics are achieved by “plot” command. Also time dependent changes of voltage, derivative of voltage, current and memristance values have been observed by scopes. Fig.6 shows voltage and derivative of voltage graphics. Top graph is voltage versus time, bottom graphic is derivative of voltage versus time. Fig.7 shows current and memristance graphics. Top graph is current versus time; bottom graph is memristance versus time.

![Fig.6 v and dv/dt graphics versus t](image)

![Fig.7 i and m graphics versus t](image)
C. Results and Comparisons

In this section, results of proposed model and comparison of this model with other publications will be given.

Current-voltage characteristic and memristance-voltage characteristic of proposed memristor model is shown in Fig.8 and Fig.9 respectively.

I-V characteristic of proposed memristor model is obtained according to control equations. Written control equations for processing of model are as follows:

\[
\begin{align*}
\text{Region} = \left\{ \\
1. \text{region for } -V_2 \leq v \leq V_2 \text{ and } & \frac{dv}{dt} > 0 \\
2. \text{region for } V_1 \leq v \leq V_2 \text{ and } & \frac{dv}{dt} < 0 \\
3. \text{region for } -V_1 \leq v \leq V_1 \text{ and } & \frac{dv}{dt} < 0 \\
4. \text{region for } -V_2 \leq v \leq -V_1 \text{ and } & \frac{dv}{dt} < 0 
\end{align*}
\]

I-V and M-V characteristics of proposed model are compared with other publications [13], [14]. Vourkas& Sirakoulis and Joglekar& Wolf models are based on HP memristor model. Proposed model is based on PWL memristor model so there is a difference between these characteristic because of that. Proposed model has linear characteristics but other models have nonlinear characteristics. The outlines of characteristics are same without this difference. Comparison of I-V and M-V characteristics are shown in Fig.10 and Fig.11 respectively. In Fig.10; red line represents Vourkas& Sirakoulis model, green line represents Joglekar& Wolf model and cyan line represents proposed model. In Fig.11; green line represents Vourkas& Sirakoulis model, red line represents Joglekar& Wolf model and cyan line represents proposed model.

This study is also an improved version of our previous study [15]. The results of previous study and these results are compatible. Also the results of this study are more compatible to Vourkas & Sirakoulis and Joglekar & Wolf models. Previous study had a gap between first and last values of both characteristics but in this study the gap is vanished. And so this model provides more suitable results.

III. CONCLUSION

In this paper, a new PWL memristor model is proposed. I-V and M-V characteristic of this model are obtained and compared with other publications [13]-[15]. The results of proposed model are better than results of [15]. This model will be used different circuit applications for future studies.
REFERENCES

EKF Based Generalized Predictive Control of Nonlinear Systems

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Abstract—In this paper, Autoregressive with exogenous input (ARX) and dynamic neural network (DNN) based generalized predictive control (GPC) methods are designed to control of nonlinear systems. ARX and DNN models adaptively approximate the plant dynamics and predict the future behavior of the nonlinear system. While control process goes on, the poles of the ARX and DNN models are constrained in a stable region using a projection operator for structural stability. Simulation results are given to compare the tracking performances of the methods. ARX-GPC and DNN-GPC both yield good tracking performances while keeping the changes in control signal as low as possible. The simulation results show that even though ARX is a linear model, it provides acceptable tracking results as well as DNN model.

Keywords: Generalized predictive control, ARX, dynamic neural network, Kalman filter and extended Kalman filter, nonlinear systems and adaptive learning rate.

I. INTRODUCTION

Identification of systems with unknown mathematical model, control and fault detection studies keep their importance up-to-date [1]. It is a hard task to obtain a mathematical model in complex systems. In addition, need for system modelling emerges due to uncertainty, disturbances and noises. In such cases, robust or adaptive control techniques should be adopted to design a controller [8]. In adaptive control, an appropriate model is selected to approximate the actual system model. Artificial neural network (ANN) and fuzzy networks are widely used as function estimators [25], [2].

GPC is a class of model-based predictive control. When dynamics of the system are not known, the model which identifies the system has a crucial role in both predicting the future behaviour of the system and generating the future control signals. In each sampling instant first one of the produced control signals is applied to the system [3], [4]. The models which are able to adapt to the changing dynamics of systems improve GPC performance. Artificial neural network (ANN) [20], [21] and support vector machine (SVM) [9], [14] can be adopted in GPC studies.

DNNs [19] have a recursive structure. Internal states and external inputs constitute the actual inputs of these networks which are widely used in function approximation. DNNs can approximate complex nonlinear dynamics due to the merits of recursive structure and nonlinear activation function [22]. Usually they are used in prediction [6], fault detection [12], adaptive control [16] and GPC [24].

In this study, particular type DNN and AutoRegressive with eXogenous input (ARX) model based GPC are performed. ARX is a linear model while both linear and nonlinear dynamics exists in the DNN model. Models are trained by extended Kalman filter (EKF). In addition to adaptation of the parameters, poles are adapted such that they are bounded to maintain stability of the model. Thus, quick and stable online identification is obtained. In numerical simulations, bioreactor and continuously-stirred tank reactor (CSTR) benchmark systems are controlled using two methods and results are compared.

Rest of the paper is organized as follows. In Section II, DNN and ARX models are presented, model stability and EKF-based training are introduced. GPC and ARX and DNN based GPC are detailed in Section III. Simulations are given in Section IV. Finally, paper is concluded in Section V.

II. IDENTIFICATION MODELS

In this section, ARX model and the DNN model which is used in continuous time adaptive control in [13] will be studied for discrete time GPC. Section II-A and II-B present the ARX and DNN models while Section II-C introduces the model stability. Finally, EKF-based training of the models is given in Section II-D.

A. ARX Model

ARX model is simple and linear. Consider \( n_u \) and \( n_y \) are the past input and output samples to construct the ARX data. Let (1) give the output equation of a system at time instant \( k \) whose explicit output expression is unknown.

\[
y_k = f(c_k)
\]

\[
c_k = (u_k, u_{k-1}, \ldots, u_{k-n_u}, y_{k-1}, \ldots, y_{k-n_y})
\]

Output can be approximated linearly by a parameter vector \( \theta_k \in \mathbb{R}^{n_u+1+n_y} \) such as

\[
y_k = c_k \theta_k^T
\]

B. Dynamic Neural Network

Figure 1 presents internal dynamics of one neuron in the dynamic NN. States of the neurons are updated in discrete-time as given in (3) and (4).

\[
\dot{x}_{k+1} = Dx_k + AT(\bar{x}_k) + Bc_k
\]

\[
y_k = Cx_k
\]
Here, $\hat{x} \in \mathbb{R}^n$ is state vector, $c \in \mathbb{R}^m$ and $y \in \mathbb{R}^m$ are input and output vectors respectively. Nonlinear activation function $T(.)$ is tangent hyperbolic function and is expressed as

$$T(\hat{x}_i) = \begin{bmatrix} \tanh(\hat{x}_{1i}) \\ \vdots \\ \tanh(\hat{x}_{ni}) \end{bmatrix}$$  \hspace{1cm} (5)

$$\tanh(x) = \frac{e^x - e^{-x}}{e^x + e^{-x}}$$  \hspace{1cm} (6)

$B \in \mathbb{R}^{n \times m}$, $C \in \mathbb{R}^{m \times n}$ and the matrices $D$ and $A$ are as follows.

$$D = \begin{bmatrix} d_1 \\ \vdots \\ d_n \end{bmatrix}_{n \times n}$$  \hspace{1cm} (7)

$$A = \begin{bmatrix} a_1 \\ \vdots \\ a_n \end{bmatrix}_{n \times n}$$  \hspace{1cm} (8)

DNN model consists of linear ARX (AutoRegressive with eXogeneous input) model and nonlinear function $\tanh(.)$. Thus, identification of linear and nonlinear dynamic systems is aimed in a quick and efficient way. This model can be considered as sparsed Hopfield type network in means of inter-neuron connections. Connection of each neuron with itself brings to the network dynamic property. Dashed lines in Figure 1 show nonexisting connections. From this aspect, model is diagonal. Figure 2 presents diagonal dynamic model.

C. Model Stability

The results in [7], [10] were reviewed to analyze the stability of the models and stability conditions given in [15] were followed in this study. First, ARX model stability is analyzed. In the simulations ARX model is used as a second order IIR (Infinite Impulse Response) filter since $n_y = 2$ is taken (see Section IV). Parameters in the parameter vector $\theta_k$ which correspond to the past output samples are constrained with the stability condition as following.

$$\begin{cases} 1 - \theta_{k,n_u+2} + \theta_{k,n_u+3} > 0 \\ 1 + \theta_{k,n_u+2} + \theta_{k,n_u+3} > 0 \\ 1 - \theta_{k,n_u+3} > 0 \end{cases}$$  \hspace{1cm} (9)

Second, DNN model stability is analyzed. State equation belonging to the $i_{th}$ neuron in the discrete-time DNN model is given by

$$\hat{x}_i(k+1) = d_i \hat{x}_i(k) + a_i T(\hat{x}_i(k)) + b_i u_i(k)$$  \hspace{1cm} (10)

$i = 1, ..., n$, $k$ is the time index, definition of the variables and model matrices are given in the previous section. Discrete-time state solution of the model given $\hat{x}(0) = \hat{x}_0$ as the initial state is obtained as follows.

$$\hat{x}(k) = D^k \hat{x}_0 + \sum_{i=0}^{k-1} D^{k-1-i} (A T(\hat{x}(i)) + Bu)$$  \hspace{1cm} (11)

Stability of the DNN model is directly related to the stability of the states since output vector of the DNN model is linearly related to the states as given in Equation (4). Neuron in Equation (10) can be considered as a first order ARX model. Stability of the DNN model expressed in Equation (3) is guaranteed by satisfying the following conditions.

$$|d_i| < 1$$  \hspace{1cm} (12)

$$a_i \neq 0$$

$$b_{ij} \neq 0, i = 1, ..., n, j = 1, ..., m$$

Generally, $b_{ij} \neq 0$ is needed to be satisfied not for the internal stability but for the input to have effect on the output.

D. Inequality Constrained EKF Based Training

Inequality constrained EKF (ICEKF) is used to train model parameters. Parameter adaptation equations of ICEKF will be given in Section II-D.1 and training of models will be detailed in Section II-D.2.

1) ICEKF: State-space representation of a nonlinear discrete-time system is given below.

$$x_k = f(x_{k-1}) + w_{k-1}$$  \hspace{1cm} (13)

$$y_k = h(x_k) + v_k$$  \hspace{1cm} (14)

Here, $x \in \mathbb{R}^n$ is state vector, $y \in \mathbb{R}^m$ is system output, $f(.)$ is nonlinear process function vector, $h(.)$ is nonlinear measurement function vector, $w \in \mathbb{R}^n$ is process noise and $v \in \mathbb{R}^m$ is measurement noise, which both are Gaussian white noises. Extended Kalman filter can be summarized.
in two steps given $Q$ and $R$ are covariance matrices corresponding to process and measurement noises respectively.

**Time Update**

$$\hat{x}_k = f(\hat{x}_{k-1})$$

$$P_k = J_f(\hat{x}_{k-1})P_{k-1}J^T_f(\hat{x}_{k-1}) + Q_{k-1}$$

$$K_k = P_k J^T_f(\hat{x}_k) J_h(\hat{x}_k) P_k J^T_f(\hat{x}_k) + R_k)^{-1}$$

**Measurement Update**

$$\hat{x}_k = \hat{x}_k + K_k (y_k - h(\hat{x}_k))$$

$$P_k = (I - K_h J_h(\hat{x}_k)) P_k$$

(15)

(16)

In (15) and (16), $P \in R^{n \times n}$ is state estimation error covariance matrix and $K_k$ is Kalman gain. $J_f(\cdot)$ and $J_h(\cdot)$ are given in (17) and (18).

$$J_f(\hat{x}_{k-1}) = \frac{\partial f(x)}{\partial x} \bigg|_{x=\hat{x}_{k-1}}$$

$$J_h(\hat{x}_{k-1}) = \frac{\partial h(x)}{\partial x} \bigg|_{x=\hat{x}_{k-1}}$$

(17)

(18)

Let us consider there exist inequality constraints on states as given below in state estimation by ICEKF.

$$M \hat{x} \leq N$$

(19)

Parameters must be within the constraint space to satisfy the constraints. By this reason, projection is taken onto the constraint space [17].

$$\hat{x}_k = \hat{x}_k - P_k M^T (MPM^T)^{-1} (M \hat{x}_k - N)$$

$$d P_k = P_k M^T (MPM^T)^{-1} M$$

$$\hat{P}_k = P_k - d P_k$$

(20)

(21)

(22)

(23)

Projection onto the constraint space is taken as in (20) to satisfy the constraints in (9) for ARX model while in (12) for DNN model. For the DNN case, states are updated as in (3) using the parameters which are updated satisfying the constraints. Thus, states are not the ones which are estimated optimally but parameters in the vector $\theta$ are.

### III. ARX and DNN Based Generalized Predictive Control

Section III-A briefly introduces GPC while Section III-B and III-C detail the ARX-based and DNN-based GPC respectively.

#### A. GPC

Let us have a NARX (Nonlinear Auto-Regressive with eXogeneous input) data model for a nonlinear system [9].

$$y_n = f(u_{n-1}, u_{n-2}, \ldots, u_{n-n_u}, y_{n-1}, \ldots, y_{n-n_y})$$

As $\hat{y}_n$ is the reference signal and $\hat{y}_m$ is the model output, GPC aims to have the model output track the reference signal with minimum tracking error possible while keeping the changes in the control signal as low as possible. Constraints exist on the control signal.

$$\min_{u} f(u) = \sum_{k=1}^{K_u} (\hat{y}[n+k] - \hat{y}[n+k])^2 + \lambda \sum_{k=0}^{K_u} (u[n+k] - u[n+k-1])^2$$

$$= (\hat{Y} - \hat{\gamma}^T \hat{Y} - \hat{\gamma}^T + \lambda u^T \hat{L} u$$

$$- 2 \lambda u[n][u[n-1] + \lambda^2 u[n-1]]$$

Constraints: $u_{min} \leq u[n+k] \leq u_{max}$, $k = 0, 1, \ldots, K_u$

$$||u[n+k] - u[n+k-1]|| \leq \Delta u_{max}, k = 1, \ldots, K_u$$

(24)

(25)

$$\lambda$$ penalizes the abrupt changes in control signal. $K_u$ and $K_y$ are horizon values up to how many future control inputs and model outputs will be calculated. Always, $K_u < K_y$ is satisfied. $\hat{Y} = [\hat{y}_1 \ldots \hat{y}_{K_y}]^T \in R^{K_y}$ and $\hat{Y} = [\hat{y}_1 \ldots \hat{y}_{K_y}]^T \in R^{K_y}$. At each time instant, to make the system output track the reference signal for future $K_y$ samples, control input

$$L = \begin{bmatrix}
2 & -1 & 0 & \ldots & 0 & 0 \\
-1 & 2 & -1 & \ldots & 0 & 0 \\
0 & -1 & 2 & \ldots & -1 & 0 \\
0 & 0 & -1 & \ldots & 2 & -1 \\
0 & 0 & 0 & \ldots & -1 & 1
\end{bmatrix}$$

(26)
vector \( \mathbf{u} \in \mathbb{R}^{K_u+1} \) is generated and first element in the vector is applied to the system. To predict the future behaviour of the system whose output function is unknown, an appropriate model to approximate that system is used. Also that model is utilised for the gradient information which is necessary to update the control signal at each time instant. This update is expressed as follows.

\[
\mathbf{u}_k = \mathbf{u}_{k-1} + \Delta \mathbf{u}
\]  
(27)

When Gauss-Newton modification is employed,

\[
\Delta \mathbf{u} = -\mu \left( \frac{\partial^2 f(\mathbf{u})}{\partial \mathbf{u}^2} \right)^{-1} \frac{\partial f(\mathbf{u})}{\partial \mathbf{u}}
\]  
(28)

is obtained and \( \mu \) denotes the step size. It can be calculated optimally using one of the one-dimensional optimization methods in the literature. Gradient vector is the following.

\[
\frac{\partial f(\mathbf{u})}{\partial \mathbf{u}} = -2 \left( \frac{\partial \tilde{\mathbf{Y}}_n}{\partial \mathbf{u}} \right)^T (\tilde{\mathbf{Y}}_n - \hat{\mathbf{Y}}_n) + 2\lambda \mathbf{L} \mathbf{u} - 2
\]  
(29)

If derivative of (29) is taken to obtain Hessian matrix, a term \( \left( \frac{\partial^2 \tilde{\mathbf{Y}}_n}{\partial \mathbf{u}^2} \right) \) is generated. But it can be ignored since it has small value. Thus, Hessian is approximated as

\[
\frac{\partial^2 f(\mathbf{u})}{\partial \mathbf{u}^2} \approx 2 \left( \frac{\partial \tilde{\mathbf{Y}}_n}{\partial \mathbf{u}} \right)^T \left( \frac{\partial \tilde{\mathbf{Y}}_n}{\partial \mathbf{u}} \right) + 2\lambda \mathbf{L}
\]  
(30)

Considering (24), model output depends on the control signals who have a time index value which is smaller than or equal to that of the model output. Thus, the term \( \left( \frac{\partial \tilde{\mathbf{Y}}_n}{\partial \mathbf{u}} \right) \) is expressed as follows.

\[
\frac{\partial \tilde{\mathbf{Y}}_n}{\partial \mathbf{u}} = \begin{bmatrix}
\frac{\partial y[n+1]}{\partial u[n]} & \frac{\partial y[n+1]}{\partial u[n]} \\
\frac{\partial y[n+2]}{\partial u[n]} & \frac{\partial y[n+2]}{\partial u[n]} \\
\vdots & \vdots \\
\frac{\partial y[n+K_u]}{\partial u[n]} & \frac{\partial y[n+K_u]}{\partial u[n]}
\end{bmatrix}
\]  
(31)

Computational load of the derivatives depends on the model.

**B. ARX Based GPC**

Since the system is approximated by ARX model, \( \frac{\partial \hat{\mathbf{Y}}_n}{\partial \mathbf{u}} \) is obtained based on that model. Considering (2), future output prediction by the model is given by

\[
\hat{y}_{k+l} = \mathbf{c}_k + \mathbf{h}_k^T \mathbf{u}_k, \quad l = 1, \ldots, K_y
\]  
(32)

It can be written explicitly

\[
\hat{y}_{k+l} = \sum_{i=1}^{n_u} \theta_{k,n_u+1+i} \hat{y}_{k+i-1} + \sum_{i=0}^{n_u} \left\{ \begin{array}{ll}
\theta_{k,i+1} u_{k+i-1} & k - K_u < i \\
\theta_{k,i+1} u_{k+K_u} & k - K_u \geq i
\end{array} \right.
\]  
(33)

Thus, partial derivative expression will be

\[
\frac{\partial \hat{y}_{k+l}}{\partial u_{k+h}} = \sum_{i=1}^{n_y} \frac{\theta_{k,n_u+1+i}}{\partial u_k} \frac{\partial \hat{y}_{k+i-1}}{\partial u_k} \delta_1(k - i - 1) + \sum_{i=0}^{n_u} \left\{ \begin{array}{ll}
\frac{\theta_{k,i+1} u_{k+i-1}}{\partial u_k} & k - K_u < i \\
\frac{\theta_{k,i+1} u_{k+K_u}}{\partial u_k} & k - K_u \geq i
\end{array} \right.
\]  
(34)

\( \delta_1 \) is the unit step function. Obtained partial derivative is substituted in (29) and (30) to obtain the gradient vector and Hessian matrix.

**C. DNN Based GPC**

Since the system is approximated by DNN model, \( \frac{\partial \hat{\mathbf{Y}}_n}{\partial \mathbf{u}} \) is obtained based on that model. Using (3) and (4), model output can be written alternatively as following.

\[
\hat{y}_k = \sum_{j=1}^{n} c_j (d_j x_j + a_j T(x_j) + [b_{j1} \ldots b_{jm}] \mathbf{u}_k)
\]  
(35)

\[
v_{jk} = [b_{j1} \ldots b_{jm}] \mathbf{u}_k
\]  
(36)

\[
\hat{y}_k = \sum_{j=1}^{n} c_j (d_j x_j + a_j T(x_j) + v_{jk})
\]  
(37)

And the future output prediction by the model is given by

\[
\hat{y}_{k+l} = \sum_{j=1}^{n} c_j (d_j x_j + a_j T(x_j) + v_{j,k+l}), \quad l = 1, \ldots, K_y
\]  
(38)

where

\[
v_{j,k+l} = \sum_{i=1}^{n_u} b_{j,n_u+1+i} \hat{y}_{k+i-1} + \sum_{i=0}^{n_u} \left\{ \begin{array}{ll}
\sum_{i=0}^{n_u} b_{j,i+1} u_{k+i-1} & k - K_u < i \\
\sum_{i=0}^{n_u} b_{j,i+1} u_{k+K_u} & k - K_u \geq i
\end{array} \right.
\]  
(39)

Thus, partial derivative expression will be

\[
\frac{\partial \hat{y}_{j,k+l}}{\partial u_{k+h}} = \sum_{j=1}^{n} c_j \frac{\partial v_{j,k+l}}{\partial u_{k+h}}
\]  
(40)

\[
\frac{\partial v_{j,k+l}}{\partial u_{k+h}} = \sum_{i=1}^{n_y} \frac{\theta_{j,n_u+1+i}}{\partial u_k} \frac{\partial \hat{y}_{k+i-1}}{\partial u_k} \delta_1(k - i - 1) + \sum_{i=0}^{n_u} \left\{ \begin{array}{ll}
\frac{\theta_{j,i+1} u_{k+i-1}}{\partial u_k} & k - K_u < i \\
\frac{\theta_{j,i+1} u_{k+K_u}}{\partial u_k} & k - K_u \geq i
\end{array} \right.
\]  
(41)

\( \delta_1 \) is the unit step function. Obtained partial derivative is substituted in (29) and (30) to obtain the gradient vector and Hessian matrix.

**IV. COMPUTER SIMULATIONS**

ARX-based and DNN-based GPC controllers were tested on bioreactor [5] and continuously stirred tank reactor [23] systems.
A. Bioreactor Control

Bioreactor is a second order benchmark system to test tracking performance of the controllers.

\[
\begin{align*}
\dot{x}_1(t) &= -x_1(t)u(t) + x_1(t)(1 - x_2(t))e^{(x_2(t) + x_2(t))} \\
\dot{x}_2(t) &= -x_2(t)u(t) + x_1(t)(1 - x_2(t))e^{(x_2(t) + x_2(t))} \\
&\quad \quad \quad + x_1(t)(1 - x_2(t))e^{(x_2(t) + x_2(t))} \left( \frac{1 + \beta}{1 + \beta - x_2(t)} \right)
\end{align*}
\]

(42)

\(x_1(t)\) and \(x_2(t)\) are cell concentration and amount of nutrients per volume. Control signal \(u(t)\) is the flow rate. \(\eta\) is time-varying parameter of the process and has a nominal value of 0.48. Controllers were employed to make the reactor output track desired reference value with minimum tracking error possible. GPC parameters are \(K_y = 10, \quad K_u = 2, \quad \lambda = 0.01, \quad u_{\min} = 0, \quad u_{\max} = 2, \quad \Delta u_{\max} = 0.2, \quad u_n = 2, \quad n_y = 2\). Sampling period is \(T_s = 0.01\) s. For the DNN-based GPC case, number of states is set \(n = 5\). In the simulation, \(\eta(t) = 0.48 + 0.06\sin(0.05\pi t)\) oscillates around its nominal value. Figure 3 shows reference tracking and produced control signal by ARX-based GPC controller while Figure 4 shows time evolution of parameters. Similarly, controllers are compared in terms of Root-Mean-Squared-Error (RMSE) and power of the produced control signal \(P_u = \frac{1}{N} \sum_{k=1}^{N} |u[k]|^2\) in Table I. ARX-based GPC controller tracks the reference signal with little oscillations while DNN-based GPC controller performs smoother tracking as expected. However, it has more overshoot compared to ARX-based GPC. Control signal is less aggressive in DNN-based GPC. ARX-based GPC has still acceptable tracking performance.

**TABLE I**

<table>
<thead>
<tr>
<th>Controller</th>
<th>RMSE tracking</th>
<th>(P_u)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARX-based GPC</td>
<td>0.0105</td>
<td>1.3401</td>
</tr>
<tr>
<td>DNN-based GPC</td>
<td>0.0099</td>
<td>1.2952</td>
</tr>
</tbody>
</table>

Fig. 5. Bioreactor reference tracking and control signal produced by DNN-based GPC controller.

Fig. 6. Time evolution of parameters in control of bioreactor by DNN-based GPC controller.

B. CSTR Control

Continuously stirred tank reactor is a third order highly nonlinear system on which tracking performance of the
controllers were tested.

\[ \dot{x}_1 = 1 - x_1 - D_{a1}x_1 + D_{a2}x_2^2 \]
\[ \dot{x}_2 = - x_2 + D_{a1}x_1 - D_{a2}x_2^2 - D_{a3}d_2x_2^2 + u \]
\[ \dot{x}_3 = - x_3 + D_{a3}d_2x_2^2 \]

\[ D_{a1} = 3, D_{a2} = 0.5, D_{a3} = 1, d_2\text{nom} = 1, y = x_3 \]  

(43)

\( u(t) \) is the control signal and \( d_2 \) is time-varying parameter of the process which has a nominal value of 1. Controllers were employed to make the reactor output track desired reference value with minimum tracking error possible. GPC parameters are \( K_y = 10, K_u = 2, \lambda = 0.1, u_{\text{min}} = 0, u_{\text{max}} = 1, \Delta u_{\text{max}} = 0.1, n_u = 2, n_y = 2 \). Sampling period is \( T_s = 0.1 \) s. For the DNN-based GPC case, number of states is set \( n = 5 \). Figure 7 shows reference tracking and produced control signal by ARX-based GPC controller while Figure 8 shows time evolution of parameters. Similarly, Figure 9 shows reference tracking and produced control signal by DNN-based GPC controller while Figure 10 shows time evolution of parameters.

ARX-based GPC controller. After the parameters of DNN-based GPC controller sets approximately to their stationary values, it begins performing as smooth tracking as ARX-based GPC does. This is the reason why ARX-based GPC has little smaller tracking RMSE value.

V. CONCLUSION

This study presents a comparison of ARX and DNN models in GPC scheme. Tracking performance of models were compared on bioreactor and CSTR systems which are both nonlinear benchmark systems. Even though ARX is a linear model, it has proven to be an acceptable model for generalized predictive control of nonlinear systems. Moreover, structural stability is maintained in both models by constraining the poles in a stable region. As a general result,
ARX and DNN models are adopted successfully in GPC scheme for both systems.

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REFERENCES
ACTIVE FILTER DESIGN USING CUCKOO SEARCH ALGORITHM

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Abstract—In this paper, Cuckoo search optimization algorithm is used to select the standard component values for active filter design by means of fitness function and constraints in order to facilitate design tasks of designers. Conventionally after designers solve circuit, they select the nearest standard component values, which are available in the market, instead of calculated one. However, this process causes design errors which have to be recalculated. From this perspective, unlike conventional method, Cuckoo Search uses a set of solution, which is discreet component values and fitness function to minimize the error. As a result of this work, Cuckoo Search algorithm has been successfully implemented to this filter design process for searching the optimum discreet component values of the solution space.

Keywords—Cuckoo search, filter design, optimization

I. INTRODUCTION

In the conventional analogue circuit design methods, component values are generally considered ideal and limitless. However, electronic components are produced in specific standard values in order to reduce the design costs. Consequently, the analogue circuit components to be used are selected from the specific standard components which are available in the market. In the traditional methods, designers make some assumptions when they know the status of the resolution of the analogue circuit in order to facilitate the circuit, to reduce the solution space and to work in the desired circuit status. In these assumptions, some components are fixed or selected in multiples of one another. This process allows us to search the solution in a smaller area by narrowing the solution space. But this gives rise to potential better solution would be ignored. Also these assumptions restrict the designer and cause some components remain constant value. These acceptances cause undesirable product errors to be fixed.

In the design of analogue circuits, to reduce the mathematical operation load and loss of time, it has been proposed different methods correspond to the classical method. Inspired by nature as an alternative calculation methods developed with Genetic Algorithm, Ant Colony Algorithm, Tabu Search Algorithm, Simulated Annealing, Bee Colony Algorithm, Firefly Algorithm, Cuckoo Search, Particle Swarm Optimization and differential evolution etc., heuristic algorithms can be used for such a complex and burdensome problems[1]. These algorithms generally include objective function expressing the problem and solution space. Thus, suitable results can be obtained with such difficult problems.

In the literature, David et al. performed a low pass active filter design using genetic algorithms. They examined the effect of the changing crossover and mutation rates to the results in the genetic algorithm. They also obtained quite successful results in the standard component selection compared with the conventional methods[2]. Turgay et al. have made the design, using genetic algorithms, for the Sallen-Key band pass filter. They made solutions for the desired frequency and filter gain to find out component values regardless of standard components[3]. Adem Kanali made solution to find out standard values of low pass filter and Wien-Robinson filter using Ant Colony algorithm and conventional methods. He compared these algorithms each other and demonstrated that Ant Colony algorithm is more efficient rather than conventional methods[4]. Gandomi and et. showed that Cuckoo Search algorithm can be used at the solution of the basic civil engineering problems[5]. Karagul made plastic waste collection application using different algorithms. He saw that the cuckoo search algorithm provided better results than others[6].

In this study, classical method and cuckoo search algorithm are used to find out standard component values in the active filter design. Finally, results are compared with each other.

II. CUCKOO SEARCH ALGORITHM

Cuckoo Search Algorithm is proposed by Yang and Deb in 2009. Such algorithms typically used in global optimization problems[7-8]. Cuckoo Search Algorithm is based on natural behaviour of some species of cuckoo called brood parasitism. Such types of cuckoo that lays its eggs into the appropriate nests and throws eggs from the nests with the possibility of hatching. When host bird arrive the nest, it may not recognize the foreign egg. Therefore, large number of hosts exposed to brood parasitism. But if host bird recognises the foreign egg, it
may throw the egg from nest or leave the nest to build new one. Yang and Deb used their idealised rules for this fiction [7-8]:

- Each bird can lay one egg and drop one egg in a random nest at a time.
- Quality solutions are transferred to the next generations.
- The number of nests is constant and host can discover foreign egg by probability pa ∊ (0,1). If it happens, host can either throw the egg and leaves in the same nest or abandons the nest to build new one.

Heuristic algorithms reach best solution by means of global and local searching. To reach the best solution, they should discover other potential solutions. From this perspective, Cuckoo search algorithm is developed algorithm by balancing local random walk and global random walk.

Local random walk equation is expressed as below;

$$x_i^{t+1} = x_i^t + as \otimes H(p_a - \varepsilon) \otimes (x_j^t - x_i^t) \quad (1)$$

Local random walk, which is expressed the equation (1), is determined by a random permutation of $x_j^t$ and $x_i^t$. $H(u)$ is Heaviside step function. While $\varepsilon$ is a parameter that comes from gaussian distribution, $s$ is step length.

Global random walk is carried out by Levy Flight as following equation;

$$x_i^{t+1} = x_i^t + \alpha L(s, \lambda) \quad (2)$$

Levy Flight is performed in order to produce new generations. Moreover, not only $\alpha > 0$ is selected but also levy flight can be scaled according to problem size.

When looked over the equations, deduced that next status depends on current status and transition probability. Best solution is obtained by keeping good solutions in the solution set.

Cuckoo Search algorithm is given in Fig 1. Firstly, objective function, which defines problem, is determined. Subsequently, random and limited initial values of solution set of population are assigned and stopcriterion is determined to make the running algorithm stopped. Loop is generated to search until the suitable solution is obtained. In the loop, new potential solution is generated by Levy Flight and if the potential solution was better than old ones, new potential solution was kept by evaluating their fitness. After that, as a part of this algorithm feature, new potential solution is generated by probability of pa and better ones kept again. After the iteration accomplished, stop criteria checked again. If stop criteria was not suitable, then iteration would continue again. Otherwise iteration would be finished and results would be visualised.

begin
Objective function $f(x) = (x_1, \ldots, x_n)^T$
Generate initial population of $n$ host nests $x_i$ ($i=1, 2, \ldots, n$)
while ( stop criterion )
Get a cuckoo randomly by Levy flights
evaluate its quality/fitness $F_i$
Choose a nest among $n$ randomly
if ($F_i > F_j$)
Replace $j$ by the new solution
end
A Fraction ($p_a$) of worse nests are abandoned and new ones are built;
Keep the best solutions
Rank the solution and find current best
end while
postprocess results and visualization
end

Fig 1. Cuckoo Search Algorithm[7]

III. ACTIVE FILTER DESING

Filter circuit is defined as passing circuit of specified part of sent or received signal[9]. While filters are used to be passed the specific band of signal in Communication, Biomedical and Defence Industries, for example in Power Electronic, they are used to maximize active power by reducing Total Harmonic Distortion. Filters are classified to high-pass filter, low-pass filter, band-pass filter and band-stop filter. According to the used components, Passive filters typically are made of the inductor, capacitor and resistance, whereas active filters are made of not only resistors, capacitors, but also amplifiers[10].

A. State Variable Active Filter

In this work, state variable active filter, as known Kerwin-Huelsman-Newcomb, is used and its schematic image is given in Fig 2. This low pass filter is totally specified by band passgain $(H)$, band pass cut-off frequency $(\omega_0 = 2\pi f_0)$ and selectivity factor $(Q)$. These parameters determine the desired operating status of filter. Kerwin-Heulsman-Newcomb Active Filter is used and its parameters are expressed as below [2-4, 10]

$$H = \frac{R_2(R_3 + R_4)}{R_3(R_1 + R_2)}$$

$$\omega_0 = \sqrt{\left(\frac{R_1}{R_3}\right)\left(\frac{1}{C_1C_2R_5R_6}\right)}, \quad (3)$$

$$Q = \frac{R_3(R_1 + R_2)}{R_1(R_3 + R_4)} \sqrt{\frac{C_1R_4R_5}{C_2R_3R_6}}$$

Electronic, they are used to maximize active power by...
B. Implementation

In this work, pa, which is one of the control parameter of Cuckoo Search Algorithm, is determined as 0.25[11]. Later, size of population is determined as 80 for each component variable. 8 different component variables are determined to solve the problem. Standard of resistor was selected E24 and standard of capacitor was selected E12 according to Electronic Industries Association (EIA) norms. Subsequently, solution set was generated by random values within boundary. Afterwards, fitness function (4) and constraint (5) were determined. Fitness function was determined as percentage difference of desired values and results, for selectivity and frequency. Also, constraint was determined that both half gain, which is desired, must be smaller than filter gain and one and half gain, which is desired, must be greater than filter gain.

\[
F(R_n, C_n) = \left[ \frac{Q-Q_{\text{desired}}}{Q_{\text{desired}}} \right] + \left[ \frac{\omega_0-\omega_{0\text{desired}}}{\omega_{0\text{desired}}} \right]
\]

Constraint:

\[
0.5H_{\text{desired}} \leq H \leq 1.5H_{\text{desired}}
\]

After each nest of solution set was evaluated by means of fitness function, algorithm was implemented until stop criteria was obtained. For this work, stop criteria was defined that, either the error of process reaches under 2% or iterations reach to 1000 steps. When the algorithm begins to work, firstly global search was started. After global search finished, good solutions would be kept. Subsequently, local search was started and it would try to approach best solutions among the good solutions. These local random walk and global random walk cause to explore the undiscovered solutions and not to provide to stick in local points.

Both conventional method and cuckoo search algorithm were implemented to this filter called Kerwin-Huelsman-Newcomb Filter. The specifications chosen were selected as 510000Ω, 13000Ω, 820000Ω, 4700Ω, 1.2x10⁻⁷ F, 1x10⁻¹¹ F, 1.4158. Results are given in Table 1 for the Cuckoo Search Algorithm and Conventional Method. Error of Cuckoo Search algorithm was obtained about 0.86%, on the other hand error of Conventional Method was obtained about 14.36%. According to results, error of Cuckoo Search Algorithm has remained within the specified error border. Cuckoo Search Algorithm was provided closer results to the specified parameters, which are frequency (ω₀) and selectivity (Q), than Conventional Method. On the other hand, Conventional Method was provided closer band pass gain (H) than Cuckoo Search Algorithm. The reason for this is that band pass gain was determined as a constraint in Cuckoo Search Algorithm and nevertheless its result was remained specified interval.

IV. CONCLUSIONS

In this work, Cuckoo Search algorithm is used to determine standard component values for active filter design. Mathematical effort and wasting time disappeared by using Cuckoo Search Algorithm compared to conventional method. Results of Cuckoo Search Algorithm have less error and more successful than Conventional Method as given in Table 1. The results are different for each program, although the run can produce the values of the standard circuit components providing the required conditions.

Obtained results showed that the Cuckoo Search algorithm can be successfully applied to this area and it is not dependent on a specific circuit model. Thus, it can be applied to more complex circuits.

REFERENCES


Petri Net Modelling of a Smart Building as a Cyber Physical System

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Abstract—In recent years, systems consisting of both physical and computational elements, called Cyber Physical Systems (CPSs), have entered into our lives. These systems are becoming increasingly important because of their wide application area such as smart buildings, intelligent manufacturing processes, energy grids, healthcare devices, smart agriculture and etc. In this work, CPSs are considered by means of a smart building application. Firstly, CPSs are introduced and their features are explained. Then, a smart building is considered for emphasizing and illustrating the importance of CPSs. In order to display working mechanism of computational and physical components of the building and to provide easy trace of the evolution of overall system, models of building components are developed via Petri net, which is a mathematical and graphical tool for modelling and analysing discrete event systems.

Keywords—Cyber physical system, Petri nets, smart building, sensors, communications

I. INTRODUCTION

In recent years, systems consisting of both physical process and computational elements, called Cyber Physical Systems (CPSs), have entered into our lives. The physical process is monitored or controlled by the computational (cyber) system, which is a networked system of several devices with sensing, computing and communication capabilities. Developments in sensor and information technology, smaller and cheaper sensor solutions, development of cheap and different communication methods as well as more powerful embedded control system allow CPSs to become widespread rapidly. These systems are becoming increasingly important because of their wide application area such as smart buildings, intelligent manufacturing processes, energy grids, healthcare devices, smart agriculture and etc.

In the literature, many works have been presented on CPSs. Despite its wide-spread use, the term ‘Cyber-Physical System’ does not come with a uniform meaning. It is often used as a synonym for ‘system in which computing interacts with the physical world’ or ‘networked embedded system’, or ‘system of systems’. The disruptive nature of cyber-physical systems has the potential to substantially change the way of addressing the key questions of modern societies, and specifically the European challenges including Well-Being, Clean Energy, Integrated Transport, and Resource Efficiency, by providing smart answers to these questions.

In the CyPhERS project [1], the following five key areas were chosen to illustrate the potential of cyber-physical systems using future scenarios of 2030, and identify strengths, weaknesses, threats and opportunities of Europe: Transport, Energy, Well-Being, Industry, Infrastructure. Authors introduced model-based design methodology for cyber physical systems and evaluated it through the development of the Tunnelling Ball Device (such as automotive engine control) in [2]. In [3] a qualitative and quantitative empirical study of the state of the art in CPS verification and validation is conducted. An approach to increase resilience in a cyber-physical system from errors in the high-level control logic is presented in [4].

This approach, monitors run-time commands in order to maintain a safety invariant. Although this method seems to be general and powerful, the main drawback is the cost of performing part of the checking at run time. Hence, authors also introduce how to perform this operation offline. In [5], Petri net is used as a formal tool for nondeterministic non-interference security model specification of cyber-physical system and is shown to be applicable to abstract pipeline distribution flow network system. A generalized Petri net model is presented in [6] to formulate the manufacturing processes, and a traceability model is automatically built by model transformation. In that work, model-based algorithms are proposed for enabling back-tracking to the source of an item with detailed productive data. Authors of [7] focus on another important human–machine interaction problem for smart building systems, which concerns conflict detection during the interaction process between multiple users and the system. They design a rule conflicts detection algorithm, which can detect conflicts between two rules as well as cycle conflict/multi-cross contradiction among multiple rules. In [8], a smart Air Conditioner scheme is proposed and its adaptation to a Smart Home system is presented. Petri net model of the smart Air Conditioner is developed in order to enable a good general view of the operation of the Smart-Air Conditioner.

In this work, CPSs are considered by means of a smart building application. Firstly, CPSs are introduced and their features are explained. Then a smart building is considered for emphasizing and illustrating the importance of CPSs. In order to display working mechanism of computational and physical components of the building and to provide easy trace of the evolution of overall system, models of building components are developed via Petri net.
II. PETRI NETS

A Petri net (PN) is a directed bi-partite graph which consists of finite set of places represented by circles, finite set of transitions represented by bars and arcs directed from places to transitions or from transitions to places, which express the conditions required for an action to be feasible and its consequences when it occurs. The places from which an arc runs to a transition are called the input places of the transition; the places to which arcs run from a transition are called the output places of the transition. A place may contain tokens denoted by black dots.

The distribution of tokens over the places of a net is called a marking that corresponds to a state of the modelled system. A transition is the marking vector, \( m \), \( m \in \mathbb{N}^P \), presented by bars, \( p \in P \), \( m \) is the marking vector \( m \) taking time, an enabled transition matrix, corresponding to all \( A \) transition \( t \in T \) is the marking vector, \( m \), \( m \in \mathbb{N}^P \), \( m \) is the output matrix that specifies the arcs directed from places to transitions,

\[
O : P \times T \rightarrow N
\]

is the output matrix that specifies the arcs directed from transitions to places and \( m_0 \) is the initial marking. Here, \( N \) is the set of nonnegative integer number. \( M : P \rightarrow N \) is the marking vector, \( M(p_i) \) indicates the number of tokens, represented by black dots, assigned by marking \( M \) to place \( p_i \).

Example 1: The PN model given in Fig. 1 is represented by

\[
P = \{ p_1, p_2, p_3, p_4, p_5, p_6, p_7 \}, T = \{ t_1, t_2, t_3, t_4, t_5, t_6 \} \text{ and } m_0 = [1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0]^T.
\]

Input and output matrices of this PN are given as follows:

\[
N = \begin{bmatrix}
0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\]

\[
O = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\]

III. CYBER PHYSICAL SYSTEMS

A. General Review

There are mainly two parts called as physical world and cyber world in CPSs. Physical world consists of sensors, devices and actuators as parts of a real physical process, while cyber world consists of a controller used to manage the physical process, a database storing data related to the physical system, an algorithm concerning the usage, safety and process of the data of the physical system, a scenario and security units. Each component of physical world and cyber world communicates through a wireless sensor and appliance (actuator) network. Information regarding physical process is received through various sensors and transmitted to cyber world. In order physical process to work better, this process is controlled in cyber world by means of developed algorithms and scenarios as well as data taken from sensors. In Fig. 2, corresponding structure of a CPS is given.

![Fig. 2 The structure of a cyber-physical system](image-url)
B. Smart Building

In this work, the importance of CPS is introduced by means of considering a smart building as a CPS. Traditional works on smart building systems mainly focus on issues of automatic control and energy efficiency, but omit the human–machine interaction problem. In [9] and [10], the authors address human activity recognition in the home environment, which can inform the smart building systems from the perspective of human–machine systems.

In this work, considered smart building is composed by real and virtual sensors, appliances, a wireless communication network and a controller unit.

Indoor and outdoor conditions of the smart building are detected via various real sensors, such as temperature, occupancy, light intensity and humidity. User requests concerning indoor conditions are taken via virtual sensors, thus user interfaces at different points, such as on-wall control panels, smart phones, tablets or computers.

Data taken from real and virtual sensors are transmitted to the database and the controller unit via wireless communication network. All data related to the building are stored in the cloud database and used when required. Controller unit manages the appliances in the building according to sensor outputs, user requests, developed algorithms and scenarios.

As diversity and number of sensors used in the building and variety of user requests increase, complexity of CPS increases which complicates the control and tracking of the system. In order to provide easy observation and tracing, computational and physical components of the building can be modelled via PNs which allow graphical representation as well as mathematical calculation of the evolution of the system.

In this work, two different PN models are developed for two different types of sensors: True/False sensors (i.e., occupancy, proximity and touch sensors) and sensors which can make wider range measurements (i.e., temperature, humidity and vision sensors).

PN model of True/False sensors is given in Fig. 3(a). In this model, places \( p_1 / p_2 \) represent sensor situations true(exist)/false(non-exist) while transitions \( t_1 \) and \( t_2 \) represent sensor activities.

For example, explanation of places and transitions of the PN model of an occupancy sensor, which is a kind of True/False sensor, are given in Table 1.

<table>
<thead>
<tr>
<th>Element</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_1 )</td>
<td>Occupancy exists</td>
</tr>
<tr>
<td>( p_2 )</td>
<td>No occupancy</td>
</tr>
<tr>
<td>( t_1 )</td>
<td>Occupancy is detected</td>
</tr>
<tr>
<td>( t_2 )</td>
<td>Occupancy is lost</td>
</tr>
</tbody>
</table>

PN model of sensors having wide range measurements, is given in Fig. 3(b). In this model, places, thus \( p_1, p_2, \ldots, p_n \) represent the level of sensor measurement, while transitions, thus, \( t_1, t_2, \ldots, t_s \) represent switching the status of the sensor.

As for appliances, 3 working modes and \( n \) program modes (working types), each of which offers different functionality and features, are considered for each appliance inside the building. Similar to sensors, appliances (in other words, actuators) inside the building can be modelled by PN based on the working status of these devices. In Fig. 4(a) and Fig. 4(b) general PN models of working and program modes of an appliance are given: In Fig. 4(a), places \( p_1/p_2/p_3 \) correspond to on/stand-by/off working modes and transitions \( t_1/t_2/t_3/t_4 \) represent switching the working modes of an appliance. In Fig. 4(b), places \( p_1/p_2/\ldots/p_n \) represent the program modes of the appliance and transitions \( t_1/t_2/\ldots/t_s \) represent the switching the program modes of an appliance.

![Fig. 3 PN models of (a) True/False sensors and (b) sensors with wider range measurement capability.](image-url)

![Fig. 4 General PN models of (a) working modes and (b) program modes of appliances](image-url)

Working modes and program modes of any appliance are monitored by the cyber part of the building and controlled according to the predefined algorithms and scenarios. The cyber part of the building uses the information gathered from the sensors and responds quickly to the changes inside the building.
C. Case Study

In this work, Air Conditioner (AC) and lighting processes of the smart building are considered in detail.

The lighting system of the smart building is controlled according to the room usage inside the building. Occupancy sensors and daylight sensors are integrated to the rooms. Users shall use wall control panel, smart phones, and etc. control units to send their request to open the lighting system. When any request to open the lighting system is detected, the controller switches the working mode of the lighting system from off to standby and monitors the status of occupancy and daylight sensor. If the occupancy sensor in the environment senses occupancy, and the daylight sensor detects that the illumination of the environment is insufficient, the controller switches the working mode of the lighting system from standby to on, thus the lamp turns on. As the controller controls the on, standby and off modes based on the user request and the outputs of occupancy and daylight sensors, unnecessary energy use in the lighting system is prevented. Program modes of a lighting system are specified by dimmable levels that are set due to the level of illumination. These illumination levels affect the users comfort. For this reason, the users determine the dimmable levels by using different user interfaces. PN model of lighting system is given in Fig. 5.

Explanations of places and transitions are given in Table 2 and Table 3, respectively.

<table>
<thead>
<tr>
<th>Places</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>p1</td>
<td>Working mode –on</td>
</tr>
<tr>
<td>p2</td>
<td>Working mode –off</td>
</tr>
<tr>
<td>p3</td>
<td>Working mode –standby</td>
</tr>
<tr>
<td>p4</td>
<td>Program mode-Dimmer level 100%</td>
</tr>
<tr>
<td>p5</td>
<td>Program mode-Dimmer level 60%</td>
</tr>
<tr>
<td>p6</td>
<td>Program mode-Dimmer level 30%</td>
</tr>
<tr>
<td>p7</td>
<td>Program mode-Dimmer level 10%</td>
</tr>
<tr>
<td>p8</td>
<td>User request</td>
</tr>
<tr>
<td>p9</td>
<td>No user request</td>
</tr>
<tr>
<td>p10</td>
<td>Insufficient natural lighting</td>
</tr>
<tr>
<td>p11</td>
<td>Sufficient natural lighting</td>
</tr>
<tr>
<td>p12</td>
<td>Room is occupied</td>
</tr>
<tr>
<td>p13</td>
<td>Room is unoccupied</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transitions</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>t1</td>
<td>Change the working mode from off to standby</td>
</tr>
<tr>
<td>t2</td>
<td>Change the working mode from standby to on</td>
</tr>
<tr>
<td>t3</td>
<td>User request is received</td>
</tr>
<tr>
<td>t4</td>
<td>User request is lost</td>
</tr>
<tr>
<td>t5</td>
<td>Natural lighting level &lt; set value (natural lighting)</td>
</tr>
<tr>
<td>t6</td>
<td>Natural lighting level &gt;= set value (natural lighting)</td>
</tr>
<tr>
<td>t7</td>
<td>Occupancy is detected</td>
</tr>
<tr>
<td>t8</td>
<td>Occupancy is lost</td>
</tr>
<tr>
<td>t9</td>
<td>Change the working status from on to standby</td>
</tr>
<tr>
<td>t10</td>
<td>Change the working status from on to off</td>
</tr>
<tr>
<td>t11</td>
<td>Change the working status from standby to on</td>
</tr>
<tr>
<td>t12</td>
<td>Change the working status from standby to off</td>
</tr>
<tr>
<td>t13</td>
<td>Change the dimmer level from 100% to 60%</td>
</tr>
<tr>
<td>t14</td>
<td>Change the dimmer level from 60% to 30%</td>
</tr>
<tr>
<td>t15</td>
<td>Change the dimmer level from 30% to 60%</td>
</tr>
<tr>
<td>t16</td>
<td>Change the dimmer level from 60% to 100%</td>
</tr>
<tr>
<td>t17</td>
<td>Change the dimmer level from 100% to 30%</td>
</tr>
<tr>
<td>t18</td>
<td>Change the dimmer level from 30% to 10%</td>
</tr>
</tbody>
</table>

In this study, the cooling and heating needs of the smart building are provided by an AC, which has 3 working modes as on, standby and off; and 4 program modes as cooling-normal (set value: \( T_{on} \)), cooling-economic (set value: \( T_{co} \)), heating-normal (set value: \( T_{no} \)) and heating-economic (set value: \( T_{he} \)). Note that, compared to the normal program modes, the temperature set value for the economic mode is higher in cooling mode; and lower in the heating mode (\( T_{he} > T_{on}, T_{he} < T_{no} \)).

According to the information received from occupancy sensors, temperature sensors and smart meter, working status, thus working mode and program mode of AC is determined by the controller, for protecting unnecessary operation of the device, thus reducing the cost, and improving user comfort.
Working mode of this AC is determined according to user request and room occupancy. Working mode of AC in off mode is changed to stand-by mode, if user request is received. If room occupancy is detected afterward, working mode is set to on. If the occupancy disappears, while AC is working in on mode, it turns back to stand-by mode. If user request disappears afterward, AC turns back to off; whatever its present working mode is.

Program mode of AC is determined according to outer temperature value taken from outer temperature sensor, tariff rate information taken from grid. If outer temperature is higher than 24°C, AC works for cooling, otherwise it works for heating. Program mode of AC switches between economic and normal modes according to the information taken from the grid (smart meter). If the tariff rate is expensive, AC is switched to economic mode otherwise it works in normal mode. PN model of the considered AC system is given in Fig. 6.

In all PN models used in smart building, the places show the status of sensors and appliances. The transitions represent the actions or changes done by the controller inside the cyber world.

IV. CONCLUSIONS

In this work, CPSs are considered by means of a smart building application. In order to display working mechanism of computational and physical elements of the building, their models are developed via PN formalism, which is a mathematical and graphical tool for modelling and analysing discrete event systems. These models provide easy trace of the evaluation of the system. In future works, other parts of smart building will be modelled by using PNs and all developed models will be used to monitor and control the real applications. Scenarios and the corresponding centralized control algorithms will also be developed.

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Short-term Load Forecasting based on ABC and ANN for Smart Grids

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Abstract— Short term load forecasting is a subject about estimating future electricity consumption for a time interval from one hour to one week and it has a vital importance for the operation of a power system and smart grids. This process is mandatory for distribution companies and big electricity consumers, especially in liberalized energy markets. Electricity generation plans are made according to the amount of electricity consumption forecasts. If the forecast is overestimated, it leads to the start-up of too many units supplying an unnecessary level of reserve, therefore the production cost is increased. On the contrary if the forecast is underestimated, it may result in a risky operation and consequently power outages can occur at the power system. In this study, a hybrid method based on the combination of Artificial Bee Colony (ABC) and Artificial Neural Network (ANN) is developed for short term load forecasting. ABC algorithm is used in ANN learning process and it optimizes the neuron connections weights of ANN. Historical load, temperature difference and season are selected as model inputs. While three years hourly data is selected as training data, one year hourly data is selected as testing data. The results show that the application of this hybrid system produce forecast values close to the actual values.

Keywords— artificial bee colony, artificial neural network, hybrid method, short term load forecasting, smart grids

I. INTRODUCTION

Today existing power system needs to be enlarged so as to meet the future demand for electrical energy. The general purpose of the planning of electric power system is delivering the electric power to end user with some desired features such as continuous, safe, reliable and minimum price. Various plans should be made to achieve these features and load forecasting is one of the most important steps of these plans. In literature, load forecasting is divided into three categories according to the forecasting time horizons. Long term load forecast consists yearly load demand forecasts and it is used for planning future electric generation, transmission and distribution. Generally gross domestic product, population, export, import, etc. are considered as inputs in the long term load forecasting studies. Forecasting which is made in a time period ranging from one week to one year is called midterm load forecasting and it is useful for determining maintenance scheduling, hydrothermal coordination and fuel purchasing strategies [1].

Short-term load forecasting is a subject on which electric utility industry and researchers are studied for several decades and is an important process for the operations of electric power systems and smart grids. It has a critical role on generation scheduling, unit commitment and maintenance plans for generators. Short term load forecast has been made in a time period from one minute to one hour.

The concept of smart grid has become a global trend in the last years and there is not any definition of smart grid acknowledged by all institutions. For example, The Smart Grids European Technology Platform defines smart grid as “electricity networks that can intelligently integrate the behavior and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies” [2]. Smart grid is an advanced electrical network that uses control, information and communication technologies to monitoring the power system. In smart grids, energy management is performed with using some forecasts which use real time data. These forecasts are renewable production forecast, load forecast and electric price forecast. The power network can be managed efficiently by making these forecasts. Short term load forecast is also crucially important for smart grids. Recently, the demand side management becomes an emerging emphasis in the electric industry with the development of smart grid technologies. Especially in micro grids, short term load forecast helps to meet the objectives of demand side management issues like determining the electric price, determining the amount of the purchases and sales of energy and reducing the peak load value. It answers the questions of load needs such as when, how much, why and which factor effect [3].

There are many studies under the umbrella of short term load forecasting. Studies can be split into different groups according to the methods, data analyzing forms, data sets, the input variable and hourly/half-hour forecast. But, generally in review studies, they are grouped according to the methods. The used methods can be divided into three as statistical methods,
artificial intelligence methods and hybrid methods. The most commonly used techniques are based on Regression models [4], Times series models [5], [6], ARIMA models [7], Artificial Neural Network models [8], [9], Fuzzy models [10], [11], Support vector machine models [12], Particle swarm optimization models [13], Genetic algorithm models[14], [15], wavelet transform [16], ANFIS [11].

This paper focuses on a hybrid method based on the combination of artificial bee colony (ABC) and artificial neural network (ANN) for short term load forecasting. Firstly, the data is analyzed to create an accurate forecasting model and then the system inputs are determined. Historical load, temperature difference and season are selected as model inputs. While three-year hourly data is selected as training data, one year hourly data is selected as testing data.

The rest of the paper is organized as follows. Section II presents data analyzing. While section III presents a hybrid method based on the combination of ABC and ANN and describes the method in details, the testing results are given in Section IV. Section V outlines the conclusion.

II. DATA ANALYSIS

In this study, 2009-2012 hourly load consumption of Turkey and daily mean temperature of some cities which have maximum load consumption is considered for forecasting data. While load consumption data are taken from Turkish Electricity Transmission Company (TEIAS), temperature data are taken from Turkish State Meteorological Service. The data of the first three years which can be seen in Fig. 1 are used for creating the forecasting model and the data of 2012 are chosen for testing the forecasting model. There are some factors affecting the amount of electricity consumption and we can group them as time, historical load, weather conditions, major events and random events.

A. Time Factor

One of the most important factors which affect the load consumption is time factor, and it can be divided into categories such as hour, day and season. Hourly load forecasting is carried out in this study, hour factor is not considered as a model input. While day factor is discussed by grouping the week days, season factor is considered as an input for forecasting model. The hourly load consumptions of three consecutive weeks are shown in Fig. 2. As can be seen from Fig. 2, load consumption trends of each days are similar with the same day which is in the neighboring weeks. But daily load consumption trends are different from each other. The early hours’ consumption of Monday is very low compared to the other days, so Monday is selected as the first day type. Tuesday, Wednesday, Thursday and Friday daily load rhythms are similar with each other, therefore these days are named as Weekday day type. Saturday and Sunday load curves are unlike any other and each other. Thus, more day types named as Saturday day type and Sunday day type are created. So we have grouped the days in 4 day types as Monday type, Weekday type, Saturday type and Sunday type.

Seasons are also acts as time factor for short term load forecasting. Although load consumption changes according to the geography and people’s usage habits, the seasons affects meteorological variables and load consumptions. For example Turkey is a country located in the northern hemisphere. The use of electricity increases for heating purposes in winter with decreasing temperature in the air. On the contrary, the use of electricity decreases with increase temperature. In summer, it also has an opposite relationship. When the temperature rises in summer season people need to cool down and run their air conditioners and as a result electric consumption increases. In autumn and spring season, the season effects seem as a transition condition between winter and summer. In summary, season is also a time factor which affect the load consumption and we consider season as an input for short term load forecasting.
B. Historical Load Factor

The most important factor is historical load for short term load forecasting and the most of the studies in literature use the historical load as an input. As seen in Fig. 2, load curves are similar to load curves of previous week and next week. Forecasting accuracy increases by taking account previous 1-3 week load values in account, because load consumption trend does not change very much in short time period like 1-3 weeks.

C. Weather Factor

Weather factor is also important factor and these are temperature, humidity, wind speed and cloudiness. In literature studies, some various temperature data are used such as daily mean temperature, daily mean temperature difference, hourly temperature and hourly temperature difference. In this study, daily mean temperature difference is chosen as another input.

There are also some random developing major events such as earthquake, disaster and chaos which affect the load consumption, but such conditions are ignored in this study.

III. FORECAST METHOD

A. Artificial Neural Networks(ANN)

Artificial Neural Networks (ANN) is the most used method for load forecasting in literature studies. ANN is a very successful method to find the relationship between inputs and outputs. Multilayer Feed Forward Neural Network has one input, one output and usually one or more hidden layers [17]. Each node connects to each other with weights. Each node has a duty to produce result with a transfer or activation function.

Output function calculation:

\[ y_i = f_i \left( \sum_{j=1}^{n} w_{ij} x_j + \theta_i \right) \]  

Where \( f_i \) is the activation function and \( w_{ij} \) is the weight of between two neuron such as input \( j \) to neuron \( i \), \( x_j \) is the input neuron number, and \( \theta_i \) is the bias neuron \( i \).

Graphics of frequently used activation functions are illustrated in Fig. 3 and Fig. 4.

A system that has multiple input and one output is called neuron. Neurons form the network structure by combining. In this study, we used an ANN structure with two layers. The structure has input neurons, hidden layer neurons and an output neuron. Sigmoid function and linear function are used respectively for the hidden layer and the output layer.

The difference between the result which is produced by the network and the target result contains generic information. Learning in back propagation algorithm provides the calculation of weights of network by adding half of the total error. This procedure continues iteratively until it reaches minimum error [18]. General network structure is shown in Fig. 5.

The formula of the total error is half of the total square error:

\[ E = \frac{1}{2} \sum_{t=1}^{n} (\text{desired}_t - \text{calculated}_t)^2 \]  

The data is divided into two as test and learning data for the execution of the algorithm. The weights obtained at the end of the training have to include the entire training data. The training will be completed when the total error reaches its minimum value.

B. Artificial Bee Colony(ABC)

Artificial Bee Colony (ABC) algorithm is used as an optimization technique with relation between food and bees. There are three types of artificial bees and these are onlooker (observer) bees, employed bees and scout bees. The onlooker bees give information to the employed bees about food source and distance by dancing on the dance area. The employed bees visit the food source and collect nectar from these sources. The scout bees look for better resources by making a random search [19]. The working principle of the algorithm is shown in Fig. 6.
Artificial observer bees consider the probability value \( p_i \) of the food source \( fs \) that is abandoned by the observer bee, which is shown in Eq. (3), to decide the quality of food source [20]:

\[
p_i = \frac{fit_i}{\sum_{n=1}^{N} fit_n}
\]

(3)

\( fit_i \) indicates the fitness value of the calculated solution and it is shown as:

\[
fit_i = \begin{cases} 
1 + x & \text{if } x \geq 0, \\
1 + \text{abs}(x) & \text{if } x < 0
\end{cases}
\]

(4)

The source of nectar that is abandoned by the observer bee is replaced with a new source that is produced by the scout bee. Formula of the produced new source by scout bee is shown as:

\[
x_i = x_{\text{min}}^j + \text{rand}(0,1)(x_{\text{max}}^j - x_{\text{min}}^j)
\]

(5)

The every each food source is processed by employed bee and calculated solution is compared with the previous solutions.

If the new solution is equal or better, the previous solution is replaced by the new solution and saved on memory.

C. The Hybrid Model

Employed bees of ABC use the transfer function and the activation function to produce solution with artificial bee colony inputs. ANN total error value is calculated by the solution of ABC produced. Trained ANN by ABC is shown in Fig. 8.

Artificial Bee Colony and artificial neural network methods are utilized intensely on the literature. In this study, we have used a hybrid method that is combination of artificial bee colony and artificial neural network for short term load forecasting. As we mentioned before, the ANN deduces the relationship between inputs and outputs by updating network’s weights and uses back propagation algorithm such as Levenberg-Marquardt and quasi-Newton for updating network weights. ABC is a swarm based optimization technique and proves their ability for optimization. The learning speed of ANN is increased by ABC since it reaches better resources.

The interface of the developed software is shown in Fig. 7. The software is developed using Borland Delphi programming language which is one of Pascal programming languages and the data is taken from excel file. The number of input neurons, the number of hidden layer neurons and the number of output layer neurons can be changed by the user. User also can choose the activation functions. Then, the weights of the ANN are calculated by the ABC algorithm while the software is running.

<table>
<thead>
<tr>
<th>Day Type</th>
<th>Best Result</th>
<th>Worst Result</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>2,772661</td>
<td>3,020512</td>
<td>2,878151</td>
</tr>
<tr>
<td>Weekdays</td>
<td>1,720396</td>
<td>1,963968</td>
<td>1,824199</td>
</tr>
<tr>
<td>Saturday</td>
<td>2,628132</td>
<td>2,774447</td>
<td>2,351175</td>
</tr>
<tr>
<td>Sunday</td>
<td>2,652428</td>
<td>2,833766</td>
<td>2,351175</td>
</tr>
<tr>
<td>Weighted average</td>
<td>2,125328</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig. 8 The flowchart of trained ANN by ABC

(a) Best Result for Monday Day Type - 03.12.2012
(c) Best Result for Weekday Day Type - 16.02.2012
(d) Worst Result for Weekday Day Type - 03.01.2012
(e) Best Result for Saturday Day Type - 01.12.2012
(f) Worst Result for Saturday Day Type - 16.06.2012
(g) Best Result for Sunday Day Type - 29.01.2012
(h) Worst Result for Sunday Day Type - 02.09.2012

Fig. 9 Actual and Forecasted values
hybrid method can perform
years hourly data is selected as training data, one year hourly
temperature difference and season
the neuron connection
algorithm is used in ANN learning process and it
neural network (ANN) for hourly load forecasting. ABC
forecasting for official and religious holidays
Saturdays and Sundays
1200, 4848, 11
can be seen in Table 1.
results
searching
load forecasting. The learning feature of
ANN
can be use
different days and e
other day types
Monday, Saturday and Sunday).
other day types
we r
other day
artificial bee colony
with
artificial neural network model. Renewable
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term load forecasting using a hybrid intelligent method. Knowledge-Based
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A PSO Tuned Fractional-Order PID Controlled Non-inverting Buck-Boost Converter for a Wave/UC Energy System

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Abstract— In this study, a fractional order PID (FOPID) controller is designed and used to control a DC-DC non-inverting buck-boost converter (NIBBC) for a wave/ultra-capacitor (UC) energy system. Because of the energy discontinuities encountered in wave energy conversion systems (WECS), an UC is integrated to the WECS. In order to obtain the best controller performance, particle swarm optimization (PSO) is employed to find the optimum controller parameters. Integral of time weighted absolute error (ITAE) criteria is used as an objective function. Also, an optimized PID controller is designed to test the performance of the FOPID controller. The whole system is developed in Matlab/Simulink/SimPower environment. The simulation results show that the FOPID controller provides lower value performance indices than the PID controller in terms of reducing the output voltage sags and swells.

Keywords— Wave energy, ultra-capacitor, non-inverting buck-boost converter, fractional order PID controller, particle swarm optimization.

I. INTRODUCTION

Alternative energy sources such as renewable energy are highly considered in order to meet increasing energy demands all over the globe. Among the renewable energy sources, wave energy (WE) is a promising energy source. Its energy density is more available than either solar and wind energy [1]. Whereas, it has some design challenges because of the irregular sea or ocean wave characteristics and extreme weather conditions [2].

A wave energy converter (WEC) used for harvesting energy form the waves. It basically includes a turbine and a floating buoy moves up and down on the sea surface. The power production rate of a WEC is mostly depending on both of the wave height and frequency in a direct-driven WEC. So, the amplitude and frequency of the WEC output voltage fluctuates chaotically. Due to the output power of the WEC has a wide variations, it cannot directly connected to a load or grid. To overcome this problem, WECs are integrated with power electronic devices and storage units [3].

An ultra-capacitor (UC) is an electrochemical capacitor with high-capacitance value. Compared to batteries, it has a very long life cycle, high efficiency, high power density and fast charging-discharging capacity [4]. Integration of the UC to WEC with and without power electronic devices can be found in literature [5, 6, 7]. UCs can be directly connected in parallel with an energy source, especially low voltage applications [8]. Also, direct integration of an UC to energy system increases the overall system efficiency by eliminating the converter losses.

Fractional calculus has become highly popular in engineering applications, especially in control systems. One of the fractional order control method is the fractional order PID controller which is the extension of the PID controller and proposed by Podlubny in 1999 [9]. A FOPID consist of 5 parameters: the proportional gain (K_p), integral gain (K_i), order of integral (λ), derivative gain (K_d) and order of derivative (μ). These parameters increases the complexity of the controller and they should be optimized in order to obtain the best controller performance.

One of the tuning method of controller parameters is to use meta-heuristic algorithms with error-based objective functions. One of these algorithms is the PSO algorithm. PSO is developed by Kennedy and Eberhart in 1995 [10]. The algorithm is an iterative optimization method based on the stochastic movements of the swarms such as fishes and birds and it is suitable for global optimization problems.

In this study, irregular wave effects seen on generated power in WEC are regulated by using a UC unit and NIBBC in order to obtain a reliable and sustainable load voltage. The parallel connected UC to the WEC provides energy to the load when the WEC output is insufficient. The converter is controlled by both of FOPID and PID controllers for comparison. Also, PSO algorithm is used to tune the parameters of the both controllers by minimizing the ITAE performance index. Both of the system results with and without UC connection are discussed.

This paper is organized as follows. Wave energy conversion system with the subtitles wave energy converter, NIBB converter and UC modelling are presented in Section II. FOPID controller is described in Section III. PSO algorithm is given in Section IV. In Section V, the simulation results are discussed. Finally, conclusion is stated in Section VI.
II. WAVE ENERGY CONVERSION SYSTEM

The scheme of the whole system is depicted in Fig. 1. The proposed system includes wave energy converter (WEC), 3-phase passive rectifier used for translating produced AC voltage signal from waves to DC signal, UC energy storage unit, NIBB converter and the resistive load.

The aforementioned subsystems are described below, respectively.

A. Mathematical model of the Wave Energy Converter

A permanent magnet linear generator (PMLG) is modelled in this study for simulating the electrical energy dynamics of a WEC [11]. The mathematical description of the induced 3-phase voltages with 120° phase shifts are given below.

\[
V_A = -\frac{2\pi N \Phi_0}{\lambda} \cos\left(\frac{2\pi}{\lambda} x \right) \frac{dx}{dt} \tag{1}
\]

\[
V_B = -\frac{2\pi N \Phi_0}{\lambda} \cos\left(\frac{2\pi}{\lambda} x + \frac{2\pi}{3} \right) \frac{dx}{dt} \tag{2}
\]

\[
V_C = -\frac{2\pi N \Phi_0}{\lambda} \cos\left(\frac{2\pi}{\lambda} x - \frac{2\pi}{3} \right) \frac{dx}{dt} \tag{3}
\]

where \(x\) is the translator displacement, \(\lambda\) is the wave length, \(\Phi_0\) is the induced flux magnitude and \(N\) is the number of coil turns.

B. Non-inverting Buck-Boost Converter

A NIBBC is a type of switched mode DC-DC converter that is used as an interfacing circuit between the wave/UC energy system and the resistive load. Output voltage of the converter which has the same polarity with the input voltage can be lower or higher than magnitude of the input voltage. This means that the converter is able to operate either a buck or boost converter. The proposed converter topology provides a wide input voltage range with low component stress and simplicity [12].

The converter topology pointed out in Fig. 1 consists of an inductor (L), diodes (D1, D2), switching mosfets (S1, S2) and output capacitor filter (Cout). The converter parameters and design criteria are given in Table I.

Using Kirchhoff’s voltage and current laws, dynamics of the converter is described by the following equations.

\[
L \frac{di_l(t)}{dt} = (u-1)V_{out}(t) + uV_{in}(t) \tag{4}
\]

\[
C \frac{dV_{out}(t)}{dt} = (1-u)i_l(t) - \frac{V_{out}(t)}{R} \tag{5}
\]

Where \(i_l\) is the inductor current, \(V_{out}\) is the output voltage, \(u\) is the control signal representing the switches positions. (\(u=1\) means the switches are on and \(u=0\) means the switches are off) [12].

When both of the switches are ON-state, as shown in Fig. 2, both of the diodes are reverse biased. Current coming from the source flows through the inductor and so, the inductor is linearly charged. The load voltage is provided by the capacitor.

When the switches are OFF-state, the diodes are forward biased and the charged inductor supplies energy to the load and capacitor.

TABLE I

<table>
<thead>
<tr>
<th>NIBBC DESIGN PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling time (µs)</td>
</tr>
<tr>
<td>Switching frequency (kHz)</td>
</tr>
<tr>
<td>Desired output voltage (V)</td>
</tr>
<tr>
<td>Input capacitor (µF)</td>
</tr>
<tr>
<td>Output capacitor (µF)</td>
</tr>
<tr>
<td>Inductor (mΩ)</td>
</tr>
<tr>
<td>Diodes forward voltages (V)</td>
</tr>
<tr>
<td>Load resistor (Ω)</td>
</tr>
</tbody>
</table>
C. Ultra-capacitor Modelling

Different type of model topologies of UC can be found in literature. Some of these are R-C parallel branch model [13], R-C transmission line model [14] and R-C classical model [13, 15], etc. R and C are used to symbolize resistor and capacitor of the UC, respectively.

In this study, RC classical model is used to simulate UC electrical dynamics. The classical R-C topology is suitable for slow discharging applications and pulse loads. Also, it is easy to model [16]. The model equivalent circuit is shown below.

![Equivalent circuit of the RC modelled UC](image)

where $V_{UC}$ is the terminal voltage of the UC, $R_{esr}$ is the equivalent series resistance used to simulate internal resistance of the UC, $R_{epr}$ is the equivalent parallel resistance used to simulate leakage currents and $C$ is the capacitance of the UC. The mathematical description between the UC voltage and current are given in (6).

$$V_{UC(final)}(t) = I_{UC}(t) R_{esr} + \frac{1}{C} \int I_C(t) dt + V_{UC(initial)}(t)$$ (6)

Maxwell BMOD0083-P048 ultra-capacitor specifications are used for modelling of the UC. The parameters are given in Table II [17].

<table>
<thead>
<tr>
<th>TABLE II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ULTRA-CAPACITOR SPECIFICATIONS</strong></td>
</tr>
<tr>
<td>Rated capacitance (F)</td>
</tr>
<tr>
<td>ESR (mΩ)</td>
</tr>
<tr>
<td>Rated voltage (V)</td>
</tr>
<tr>
<td>Power density (W/kg)</td>
</tr>
<tr>
<td>Max. energy density (Wh/kg)</td>
</tr>
</tbody>
</table>

III. FRACTIONAL ORDER PID CONTROLLER

Fractional-order PID controller based on fractional calculus includes more than two additional parameters ($\lambda$, $\mu$) to the conventional PID controller. $\lambda$ is the order of the integrator and $\mu$ is the order of differentiator.

The FOPID controller has five parameters to be optimized in order to obtain the best controller performance. The block diagram representation of the proposed controller is shown in Fig. 4.

![Block diagram of the FOPID controller](image)

A FOPID controller transfer function representation is defined as [18]:

$$G_{FOPID}(s) = \frac{U(s)}{E(s)} = \left( K_p + \frac{K_i}{s^\lambda} + K_d s^\mu \right)$$ (7)

Where $U(s)$ and $E(s)$ are the control and error signals, respectively. In this study, FOPID controller software are performed by FOMCON Toolbox [19].

IV. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization (PSO) is a population based evolutionary algorithm developed from the simulations of bird-flocking. The first step in algorithm is that the specified number of particles are placed randomly in the d-dimensional search space and objective function of the each particle is calculated and saved at their current position [10].

Associated coordinates with the best solution is called $p_{best}$. Then, the obtained best solution is compared to each other to find the global best solution which is called as $g_{best}$. The movements of the particles are updated by using the position (X) and velocity (V) equations given in (8) and (9), respectively [20].

$$V_{i}^{t+1} = w V_{i}^{t} + c_1 r_1(p_{best}^{t} - X_{i}^{t}) + c_2 r_2(g_{best}^{t} - X_{i}^{t})$$ (8)

$$X_{i}^{t+1} = X_{i}^{t} + V_{i}^{t+1}$$ (9)
In (8) and (9), \( i \) is the particle number, \( t \) is the iteration number, \( c_1 \) and \( c_2 \) are the acceleration factors which are set to 2. \( r_1 \) and \( r_2 \) are the random numbers in the range of \([0, 1]\). \( w \) is the inertia weight which balances the global and local search. The value of the \( w \) is linearly decreased from 0.9 to 0.4 as recommended in [21]. Population size (n) and the iteration number (N) for both of the controller tuning processes are set to 10 and 20, respectively.

Since the ITAE criteria of which mathematical description given below provides a smaller overshoot and reduced oscillations than the other error-based performance indexes, it is used as an objective function [22, 23].

\[
ITAE = \int_{0}^{t} |e(t)| dt
\]

(10)

V. SIMULATION RESULTS

The WECS illustrated in Fig 1. schematically is developed in Matlab/Simulink/SimPower environment. Because the small-scale waves are considered in this study, current drawing from the generator is limited by duty cycle (\( d \)) in the range of \([0, 0.65]\). Simulations are performed for 30 seconds. The initial charge voltage of the UC is 12 V and the load resistor is 10 \( \Omega \).

The DC-DC NIBB converter used for load voltage regulation is controlled by both of FOPID and classical PID controllers. PSO algorithm is employed to tune controller parameters and ITAE performance measure is used as an objective function. Also, other error-based performance indexes : integral of squared error (ISE), integral of absolute error (IAE) and integral of time weighted squared error (ITSE) are considered for a better comparison of the designed controllers. The optimized parameters of the controllers and calculated performance measures are given in Table III and Table IV, respectively.

<table>
<thead>
<tr>
<th>Controller</th>
<th>Controller parameters</th>
<th>( K_P )</th>
<th>( K_I )</th>
<th>( \lambda )</th>
<th>( K_D )</th>
<th>( \mu )</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOPID</td>
<td></td>
<td>13.42</td>
<td>27.78</td>
<td>1.41</td>
<td>0.0153</td>
<td>0.34</td>
</tr>
<tr>
<td>PID</td>
<td></td>
<td>12.11</td>
<td>29.78</td>
<td>-</td>
<td>0.0794</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Controller</th>
<th>Performance measures</th>
<th>ITAE</th>
<th>IAE</th>
<th>ITSE</th>
<th>ISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOPID</td>
<td></td>
<td>51.39</td>
<td>3.535</td>
<td>7.129</td>
<td>1.287</td>
</tr>
<tr>
<td>PID</td>
<td></td>
<td>61.10</td>
<td>4.196</td>
<td>10.77</td>
<td>1.659</td>
</tr>
</tbody>
</table>

The simulation results are considered with and without UC unit. Since the FOPID provides a lower value performance criteria value, all results are shown with optimized FOPID controller.

The induced irregular 3-phase form in WEC with and without UC unit is depicted in Fig. 5. The converter input voltage and current is shown in Fig. 6.
Fig. 6 shows that the parallel connected UC unit to the WEC output eliminates the voltage drops encountered in a WEC because of the irregular wave effects. As a result, a more stable input voltage is obtained for the NIBBC input. WEC provides energy to the load when the induced voltage value is greater than UC charge voltage.

Fig. 7 shows the load voltage and current with and without UC unit. The WEC is alone inefficient to feed the load. The comparison of the PSO optimized FOPID and PID controllers are given in Fig. 8. The FOPID controller provides a stable voltage with increased quality than the PID controller. Also, the system response without overshoot is obtained with FOPID controller.

VI. CONCLUSIONS

In this study, an initially charged UC unit is connected in parallel with a WEC output. A NIBBC is used as an interface circuit between the WEC/UC side and the load. Thus, it is aimed to regulate the energy irregularities encountered in WEC output.

The designed WECS is tested under irregular wave condition. The rectified variable WEC/UC output voltage is applied to the NIBBC. DC-DC converter is controlled by a FOPID controller. Also, a classical PID controller is used for comparison. In tuning process of the both controller parameters, a well-known optimization algorithm PSO is employed. The ITAE is used as an objective function. The simulation results show that the FOPID provides lower value objective function value than PID controller. This means the higher quality output voltage without overshoot is obtained by using the FOPID controller.

Since the small-scale waves are considered for this study, WEC is alone inefficient to charge the UC unit. A solar or grid charged UC can be considered to increase the overall system sustainability.

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REFERENCES


Determinaton of the appropriate feature vector from the EEG signal for epilepsy diagnosis

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Abstract- Epilepsy that occurs suddenly and repeatability of seizure is a chronic neurological disorder and it is estimated that 1% of the world population suffering from epilepsy. Therefore, many studies are carried out for the diagnosis of epilepsy. In this study, we performed to determine the most significant characteristic by using electroencephalography signals (EEGs). EEG recordings that obtained from 10 normal subjects and 10 epileptic patients were conducted from Selcuk University Faculty of Medicine. Different features extraction methods that include Discrete Wavelet Transform, statistical methods were applied for identifying highest success features vectors. Different classification methods were performed for determining success of classifiers. High classification accuracy (CA) was obtained when the statistical methods was used in this new dataset. K-Nearest Neighbors (kNN) method achieved higher CA with 98% than the other classification methods.

Keywords-Epilepsy, electroencephalography, feature extraction, discrete wavelet transform.

I. INTRODUCTION

Epilepsy is a type of neurological disorder disease stemming from temporary abnormal discharges of the brain electrical activity [1] and [2]. The significant characteristic of epilepsy is recurrent seizures. Sometimes seizures may go unnoticed, depending on their presentation [3]. Therefore, automatic seizure detection, particularly if it is performed online, can be very helpful to identify segments of electroencephalography (EEG) likely to have seizures [4]. However, there still exists a need to further improve existing detection methods published in the literature. Elman Classifier was designed to acquire EEG and psycho physiological signals by Hosseini et al.[5], Kumar et al. [6] highlighted the importance of entropy-based features in recognizing EEGs with recurrent Elman Networks. Orhan et al. [7] achieved Multi-Layer Perceptron Neural Network (MLPNN) for classification of EEG signals and feature vectors were clustered by using K-means clustering method. Aydin et al. [8] developed a classification using Multilayer Neural Network (MLNN) architecture with EEG series.

Lee [9] proposed the Neural Network with Weighted Fuzzy Membership (NEWFM) to classify EEG signals. Fu [10] performed the classification of EEG signals using Hilbert–Huang transform (HHT) and Support Vector Machine (SVM) with Radial Basis Function (RBF). Joshi et al. [11] carried out classification of EEG signals using fractional linear prediction. Musselman et al. [12] proposed time-frequency distributions in the classification of epileptic activities by using SVM. Moreover, Valderrama et al. [13] identified via SVM an increased risk of epileptic seizures using a multi-feature EEG-ECG classification. A comparative study of waveform families for EEG signal classification was performed by Gandhi et al. using Probabilistic Neural Network (PNN) with SVM. Whereas Siuly et al. [14] proposed Clustering Technique-based Least q-Square Support Vector Machine (CT-LS-SVM) classification using some feature vectors, Lima et al. [15] used some SVM methods such as Lyapunov the standard SVM. We may reach the conclusion that classifies EEG signal was performed by using different classification and feature extraction methods.

EEG is a complicated and non-stationary signal and its characteristics are spatio-temporal dependent. They were not considered using statistical properties or sub-bands. The suitable feature extraction and accurate classifiers are needed for evaluation of these signals. Therefore, in this study, EEGs have been evaluated with different classifiers by extracting different features from EEGs. We carried out various classification and feature extraction methods in the same work for observing and detecting feature vectors that provide the highest success. At the same time, we observed which feature vectors on the not suitable for this dataset. On the other hand, we aim to increase the success by using determined features by means of new classification methods or hybrid systems in future work.

There is no doubt that the number of inputs is very crucial in the system since the classification method should be selected very carefully. The number of unnecessarily high inputs might decrease performance of the system or the number of unnecessarily low inputs may not give the result accurately and confidently. Due to the fact that in this paper, we used the various feature extraction methods that include statistical features and power of sub-bands features via Discrete Wavelet Transform for detecting epilepsy from EEGs.

II. MATERIALS AND METHODS

1. DATA ACQUISITION

In this study, EEG data recorded in the Department of Neurology is used with decision of Selcuk University Faculty of Medicine Hospital (Non-Invasive Clinical Research Ethics Committee No. 2014/423). We have used a total of 20 subjects (10 epileptics, 10 non-epileptics) that collected between 2012 and 2015. All of EEGs was obtained from
routine EEG recording and all subjects were awake. Their mean age of 10 epileptic patients was 39 (7 male, 3 female) and mean age of 10 non-epileptic patients was 42 (6 male, 4 female) and all EEG tracing has been converted electronically. Meanwhile, EEG recordings in different dates of two patients who are epilepsy and undergo a treatment were included to our work.

EEG recording consist of 20 channels that include 18 channels for EEG, 1 channel for electrocardiography (EKG) and 1 channel for photic stimulation. However, we used 18 channels in this study because of including brain waves. Sampling frequency is 200 Hz and each epoch consists of 15 seconds.

Recording times is different from each other due to the fact that the situation of each subject in record time is different. Moreover, dataset showing epileptic activity that is determined by specialists are selected. These dataset was created EEGs that include various waves such as sharp wave, spike, spike and slow wave, multiple spike and slow wave complex. 5 epochs are used in this study both epileptic and non-epileptic patients and the length of each epoch are composed of 3000 samples. 100 segment data for 20 subjects was obtained as a result of calculations and adjustments. Whereas a value of 1 is given for 50 epileptic data, a value of 0 is given for 50 non-epileptic data in order to classify.

2. FEATURE EXTRACTION

Feature extraction process is an important factor affecting the success of classification. Features should be determined for achieving results faster and more accurately with fewer data. Therefore, the feature vectors were computed by the usage of the Matlab (Version 7.11, R2010b) software package. Feature Vectors (FV) are divided into 3 groups respectively, Feature Vector 1 (FV1), Feature Vector 2 (FV1) and Feature Vector 3 (FV3) as a result of feature extraction as shown in Table I. The number of decomposition levels is chosen based on the dominant frequency components of the signal. The levels are chosen such that those parts of the signal that correlate well with the frequencies required for classification of the signal are retained in the wavelet coefficients [16]. In this study, the EEG signals are filtered with band-pass Butterworth filter to extract four common frequency bands, beta (β), alpha (α), and delta (δ), theta (θ). The power of subbands has been found by using the Discrete Wavelet Transform (DWT) for FV1. The wavelet function selected was Daubechies with order 4, which was also proven to be the best suitable wavelet function for epileptic EEG signal analysis [17]. Eight statistical features are extracted from each EEG channel data as they are the most representative values to describe the original signals. Experiments have shown that computing speed of classifiers and CA decreased with using of combination of all statistical features. Therefore, whereas some statistical features consists of minimum, maximum, standard deviation and variance have been found for FV2, skewness, kurtosis, interquartile range and mean absolute deviation have been found for FV3. Consequently, statistical features were divided into two groups as FV2 and FV3.

| TABLE I. FEATURE VECTORS BY USING DIFFERENT FEATURE EXTRACTING METHODS |
|---------------------------|-----------------------------|
| Name | Description |
| FV1_Pb | Average power of β in each sub-band |
| FV1_PA | Average power of α in each sub-band |
| FV1_PT | Average power of θ in each sub-band |
| FV1_PD | Average power of δ in each sub-band |
| FV2_Min | Minimum of the coefficients in each channel |
| FV2_Max | Maximum of the coefficients in each channel |
| FV2_Var | Variance of the coefficients in each channel |
| FV2_Sgd | Standard deviation of the coefficients in each channel |
| FV3_Skw | Skewness of the coefficients in each channel |
| FV3_Krt | Kurtosis of the coefficients in each channel |
| FV3_Iqr | Interquartile range of the coefficients in each channel |
| FV3_Mad | Mean absolute deviation of the coefficients in each channel |

72 (18x4) features were obtained due to the fact that 4 features were extracted every channel (18). Thus, each dataset consists of 100 segments and 72 features.

3. CLASSIFICATION METHODS

SVM and different Neural Network algorithms are often used in literature for the epilepsy diagnosis. On the other hand, in this study, we carried out different methods that include kNN, Classification Tree, Random Forest, Naïve Bayes in addition to these methods. The parameters of classifier were optimised in order to determine the highest success by various trials. The parameters of all classifier that provide the highest success is shown in Table II.

| TABLE II. LEARNING PARAMETERS OF EACH CLASSIFIER |
|-----------------------------------|-----------------------------|
| Classification Methods | Parameters |
| MultiLayer Perceptron (MLP) | Hidden layer neurons: 20 |
| Naïve Bayes | Probability estimation: Relative Frequency |
| Classification Tree | LOESS* window size: 0.5 |
| SVM | Estimate class probabilities: Yes |
| Random Forest | Normalize data: Yes |
| kNN | Unknown values ignored: Yes |

*LOESS: Local weighter regression (kernel smoothing procedure)

4. STATISTICAL CALCULATION OF PERFORMANCE

The performance of the classifier methods is assessed by the following measures.

1) True positive (TP): It identifies an input as a patient with epileptic diagnosed by the expert clinicians.
2) True negative (TN): It identifies an input as a normal that was labeled as a normal by the expert clinicians.

3) False positive (FP): The detection of epileptic that was labeled as a normal by the expert.

4) False negative (FN): The detection of a normal that was labeled as an epileptic patient by the expert. The performance of the classifier is also assessed in terms of sensitivity and specificity as follows.

Additionally, we can calculate sensitivity, specificity and accuracy values by using TP, TN, FP and FN as shown below.

(1) Sensitivity (Sens): A measure of the ability of the classifier to detect epileptic signal.

\[
\text{Sensitivity} = \frac{TP}{(TP + FN)} \%
\]

(2) Specificity (Spec): A measure of the ability of the classifier to specify normal signal.

\[
\text{Specificity} = \frac{TN}{(TN + FP)} \%
\]

(3) Accuracy

\[
\text{Accuracy} = \frac{TP + TN}{(TN + TN + FP + FN)} \%
\]

III. EXPERIMENTS AND RESULTS

In this study, we tried to find which feature vector that represents better the EEG signal using various classification methods such as MLP, Random Forest, SVM, kNN, Classification Tree and Naïve Bayes. First of all, data was organized and then extracted some feature vectors by using power of subbands and some statistical functions. 5-fold cross-validation is performed on all data when determining the success of classification methods.

It can be seen that kNN is the most successful methods with 98% CA for FV2 and 96% CA for FV3 as shown in Table III. Meanwhile, Naïve Bayes is the most successful method for FV1 with 69%. However, at the same time kNN is more successful for FV1 than other methods except for Naïve Bayes. Consequently, we can say that whereas kNN is the best classifier for this dataset, Classification Tree is the lowest classifier.

TABLE III

THE RESULTS OF TEST (EXAMPLES: 100)

<table>
<thead>
<tr>
<th>Feature Vectors</th>
<th>Naïve Bayes</th>
<th>MLP</th>
<th>Classification Tree</th>
<th>SVM</th>
<th>kNN</th>
</tr>
</thead>
<tbody>
<tr>
<td>FV1 CA</td>
<td>0.6900</td>
<td>0.6500</td>
<td>0.6700</td>
<td>0.6200</td>
<td>0.6400</td>
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<td>Sens</td>
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<td>0.7800</td>
<td>0.9400</td>
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</tr>
<tr>
<td>FV2 Spec</td>
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<tr>
<td>Sens</td>
<td>0.9000</td>
<td>0.9200</td>
<td>0.9200</td>
<td>0.9200</td>
<td>0.8400</td>
</tr>
<tr>
<td>FV3 Spec</td>
<td>0.9400</td>
<td>0.8800</td>
<td>0.9200</td>
<td>0.9000</td>
<td>0.8800</td>
</tr>
<tr>
<td>CA</td>
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<td>0.9100</td>
<td>0.8900</td>
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<tr>
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</tbody>
</table>

Confusion matrix that is true and false predictions in each feature vectors including FV1, FV2 and FV3 are given in Table IV. Whereas Naïve Bayes classifier has been found 40 true, 10 false for 50 non-epileptic data, 29 true, 21 false for epilepsy group in FV1. On the other hand, kNN has been found 49 true and 1 false both non-epileptic and epileptic data in FV2. 49 true and 1 false for non-epileptic data and 47 true and 3 false was found for FV3 by means of kNN. Confusion matrix in Table IV gives number of true and false in detail that this table is also confirmed in Table II.

TABLE IV

CONFUSION MATRIX FOR ALL FEATURE VECTORS BY USING DIFFERENT CLASSIFIER

<table>
<thead>
<tr>
<th>Classification Methods</th>
<th>Feature Vectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FV1</td>
</tr>
<tr>
<td>Naïve Bayes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
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<td></td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

Note: column represent predictions, row represent true classes

In spite of the fact that SVM and MLP are providing the highest achievement many studies in the literature, the results show that kNN provides the highest CA in our work. Meanwhile, the accuracy of classification has been finding very high with FV2.

Receiver operating characteristics (ROC) graphs that are commonly used in medical decision is a plot of class sensitivity against specificity as a threshold parameter is varied. In this study, the epilepsy/non-epilepsy decision threshold is varied in the range 0–1 as shown in Fig 1.
The ROC area is an effective method in order to compare the performance of different features. As is known, the area under the 1 value in ROC curve shows the excellent test results, whereas the area under the 0.5 value in ROC curve shows the unsuccessful test results. The gathered results showed that statistical features for this new dataset could be tried on similar dataset that includes larger data in order to test and improve. In the next study, it is planned to develop a system that allows distinguishing the differences and similarities between seizures and artifacts because even experts can give wrong decisions besides the computer systems.

**IV. CONCLUSION**

Feature extraction method and number of the features affects to reach accurate results in a faster way as well as the performance of the classifier. Therefore, it will improve the success of the classifier to determine the appropriate number and best features. In this context, different feature extraction methods were tested and the performance of the classifiers was compared. The CA for FV2 and FV3 are more successful than FV1. On the other hand, kNN gives the highest average CA of all feature vectors although Naïve Bayes is the most successful method for FV1.

**ACKNOWLEDGMENT**

This study was produced as a result of Sema Yıldırım’s PhD’s thesis in Selcuk University Institute of Science and Technology. We present our thanks to Selcuk University Faculty of Medicine Hospital for their contributions.

**REFERENCES**


A Comparison of The Programmes Using Finite Element Software in Electrical Machine Design

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Abstract—Electrical machines technology has become too dependent on finite element method (FEM) programs in our time. In this study, three programs that are sold commercially are compared over a 4-poles asynchronous machine of 1.1 kW. With this comparison, it is investigated how close the values obtained by convenience, appearance, integration and, in particular, torque calculations with the real values will be. For this, the mechanical torque value of the machine is obtained first by using the machine’s foreknown geometrical parameters and electrical parameters found by tests. Then, the magnetic flux line and density distribution and the obtained reluctance / real torque values are compared between FEM programs.

Keywords—Ansoft /Maxwell, Cedrat /Preflu, Ansys, Ansys Workbench, Induction Machine

I. INTRODUCTION

In recent years, the FE software package has been widely used in applications. The programs using these applications are Ansoft, Ansys and Cedrat. Ansoft is the most common program among these publications although all types of machine and analysis are available in Ansys. Ansys is the world's most widely used FE software package program. Cedrat is not a very popular program.

In this study, FEM software packages were compared starting from real values on a 4-pole asynchronous machine of 1.1 kW [1]. As a result, it is proposed to give an idea for electrical machine designers using finite element technology. Although this test was performed only for the asynchronous machine, it is generally useful for demonstrating the advantages and disadvantages of these programs. As a matter of fact, as a result of the variations and difficulties between theoretical calculation and reality due to the working manner of the asynchronous machine, the closer a simulation program for such a type of machine to the real value the more acceptable performance given by the simpler direct-current machines.

In essence, real criterion is considered to be torque calculation. This is because magnetic flux distributions of this machine, which has been produced commercially, have already been designed within the acceptable limits. In all simulations, the material is used with a BH characteristic given in Fig. 1 The computer system that is used for simulations is given in Table I and specifications of the test machine in Table II.

| Computer type | Laptop |
| Manufacturer   | Dell   |
| CPU            | AMD Turion 64x2 TL-50 1.60 Ghz |
| Physical RAM   | 2 GB   |
| Graphic Card   | ATI Radeon Xpress / Shared system memory |
| OS             | Windows 7 Ultimate 64 bit |
Initially analytical expressions are obtained from the values determined by the company. After calculating emf in the stator as 192 V by using the air gap magnetic flux density as 0.7 T and heyland leakage factor, the number of conductors per slot is found, by taking the equivalent pole length factor α = 0.76, as follows,

\[ z_0 = \frac{2m E_1}{N_1 4.44 f k_w \phi} \]  

(1)

where, \( E_1 \) is the voltage at motor end; \( n_1 \) is the synchronous speed; \( m \) is the phase numbers and \( X_1 \) is the short circuit reactance.

In here, \( z_0 \) is found as 69 and \( N_1 \) is the number of stator slots; \( k_w = 0.96 \) is the winding factor and \( \phi = 0.0022 \text{ Wb} \) is the air gap flux. The stator slot pitch induction is found from Eq (2):

\[ B_{da} = \frac{\tau_0}{k_w b_{da} B_{0}(1 + 0.6667 \sigma)} \]  

(2)

where, \( B_{da} \) is stator slot pitch induction (T); \( \tau_0 \), stator slot pitch; \( b_{da} \), stator tooth width; \( k_w = 0.95 \) is the iron packing factor; \( B_{0} \) is the air gap induction (T) and \( \sigma = 0.0115 \) is heyland leakage factor. The height of the yoke is found by using the below equation.

\[ h_{j1} = \frac{\phi(1 + \sigma)}{2k_w L B_{j1}} \]  

(3)

where, \( L \) is the stack length (mm) and \( B_{j1} \) is the yoke magnetic flux density and assumed to be as 1.4 T. Rotor yoke height is obtained as,

\[ \frac{h_{j2}}{2k_w L B_{j2}} = \frac{\phi}{2k_w L B_{j2}} \]  

(4)

In here, the rotor yoke height is taken as 1.2 T. Leakage reactance of stator winding is,

\[ X_{\sigma 1} = 0.5 \pi^2 \frac{\omega_1^2}{f} \lambda_1 \]  

(5)

where, \( \lambda_1 = 12.46 \) is the leakage conductance of stator winding. Then, the leakage reactance of rotor bars reduced to stator is obtained from (Eq (6)).

\[ X_{\sigma 21} = 1.6u_1 \pi^2 \lambda_2 \]  

(6)

where, \( \lambda_2 = 19.63 \) is the leakage conductance of stator winding and \( u_1 = 6.67 \times 10^4 \) is the conversion rate. The leakage factor of the rotor is obtained as,

\[ \sigma_2 = \frac{X_{21}}{X_1} \]  

(7)

Then, nominal and startup moments found from the equivalent circuit parameters are obtained as follows, respectively:

\[ T_1 = 1 + \sigma_1 \]  

(8)

\[ X_k = T_1 X_1 + T_2 X_{21} \]

By using the above relationships, the nominal moment,

\[ M_{dn} = 60 \frac{m U}{\sqrt{3}} \frac{R_{21} / s}{(R_1 + T_1 R_{21} / s)^2 + X_k^2} \text{ (Nm)} \]  

(9)

and the startup moment,

\[ M_{dy} = 60 \frac{m U}{\sqrt{3}} \frac{R_{21} / s}{(R_1 + T_1 R_{21} / s)^2 + X_k^2} \text{ (Nm)} \]  

(10)

are found as 7 and 16.84 Nm, respectively. Here, \( U \) is the voltage at motor end; \( n_1 \) is synchronous speed; \( m \) is the phase number; \( T_1 \) is the conversion rate; \( R_1 \) and \( X_1 \) are resistance and reactance of stator winding, respectively, and \( X_k \) is the short circuit reactance.

II. THE PROGRAMMES FOR ELECTRIC MACHINE DESIGN WITH FEM

A. ANSOFT

Of the products of Ansoft [2-13], Maxwell v2.6 is investigated for 2D applications, Maxwell v11.1 for 3D applications and the electrical machines module rxmprt v5 was examined. The
Disadvantages of Ansoft / Maxwell;

- **Electrostatic analysis and a geometry module are available for electrical machines:**
  The geometry of the machine is generated with rmxprt integrated as a module by using Maxwell v11.1 2D/3D program and this can be used with the versions 2.4 or 2.6 for 2D analysis. Almost every electrical machine geometry in 2D or 3D can be generated easily by v11.1 developed for Maxwell 3D applications and the rmxprt module integrated into it.

- **A translator module is available for AutoCad file:**
  A useful module, called a translator, is available in Maxwell control panel that converts Autocad DXF files, etc. to sm2.

- **Very easy-to-use:**
  The geometry part can be easily skipped in this program by converting the AutoCAD files to sm2 format with a translator. In addition, any electrical machine generated with rmxprt program can easily be exported in 2D. The BH curve can easily be obtained directly from txt file.

- **Winding tool is available:**
  Winding tool availability in the program provides convenience to the designer.

- **Graphical performance is high:**
  Maxwell 11.1 provides an excellent graphics performance in 2D/3D applications. Drawing can be easily managed with handy shortcuts using the mouse. The size of the shape does not cause much decrease in performance. Even a synchronous generator with an internal diameter of 2 m, an outer diameter of 2.8 m and a depth of 30 cm takes up the space of approximately 600 MB and offers a superior graphics performance.

- **Graphical plotting specifications are sound:**
  Plotting can be performed easily and a plotting form can be obtained including the number of lines.

- **High solution speed:**
  Solution part progress is very fast.

- **Memory and CPU performance is good**
  Program memory is suitable as drawings do not occupy too much space and the processor performances provide the results in a short time.

Disadvantages;

- **Static Analysis:**
  It does not allow professional solutions with respect to the static analysis.

- **DOS view for 2D applications:**
  The graphical interface of Maxwell v2.6 used for 2D applications is similar to the DOS programs.

- **Direct AutoCAD integration is weak:**
  Integration is not possible for direct intervention in the AutoCAD files.

- **Moderate accuracy:**
  Magnetic flux density distribution is shown in Figure 2. Although the reluctance torque values obtained as 5.53 Nm is not the realistic value, Ansoft can easily bring the simplicity together with the mastership. (Torque value is -5.53 Nm).

- **Inadequate help menus:**
  Help files achieved by F1 button on the program menu are inadequate.

In conclusion, opportunities offered by Ansoft[14] will be very useful for the researchers who will begin Magnetic field static analysis with finite elements method for the first time.

**B. CEDRAT**

Preflu2D v10.3.2 program [15-18] of the Cedrat group is analyzed here. Cedrat classifies its products as 2D and 3D. The visual quality, performance, advantages and disadvantages of this program in 2D and 3D applications were investigated and, information was given about them.

Advantages of Cedrat / Preflu:

- **Electrical machines module is available**
  The design part of the electrical machine is the result of an original design. In Cedrat’s design module, the part that is moving or the part which is fixed can be entered and a good machine geometry can be created. The meaning of the parameters in the designed asynchronous machine geometry can be displayed in the figures (with animations) available on the ready overlayers.

- **Armature reaction is taken into account:**
  In Figure 3, it can be seen that the magnetic flux lines are different from the Ansoft and Ansys programs. This is Cedrav taking the armature reaction into account and this really seems to be a significant advantage by itself.

- **Winding tool is available:**
  The winding tool available in the program provides convenience to the designer.

- **Mechanical torque calculation is available:**
  A mechanical torque calculation by Cedrat is a good specification although it can hardly approach the real torque value as can be seen in Table 3.

- **Electrical circuit module is available:**
  The electrical circuit diagram of the machine is handled separately by the Cedrat. The values of circuit elements cannot be seen with these specifications offering the possibility of making any kind of connections. Furthermore, one has to enter resistance and inductance values of each phase into
the program, as external data requires the use of other programs.

- **Graphical interface is good**
  The graphical interface is designed well although it is not as good as Ansoft.

- **Graphics performance is satisfactory:**
  Graphical result unit of Cedrat generates values suitable with what to do. Understanding of the results takes a short time with the help files. Graphics are found as desired and features of the results part make a good impression.

- **Graphical plotting specifications are very handy**
  It is possible to obtain a variety of parameters graphically and animation features are fairly advanced in graphic illustrations. Harmonic analysis can be represented graphically in spectral analysis and this makes Preflu of the Cedrat one-step ahead. In addition, all graphics can be shown in the same axis in a single window.

- **Solution speed is moderate**
  It is observed that the solution speed generates solutions at normal speed compared to other programs when it is considered to make the memory stacked.

Disadvantages:

- **2D and 3D applications are separated:**
  This is disadvantageous for those who wish to work both in 2D and in 3D.

- **Hard-to-use:**
  The web browser is opened by pushing the help button and the help files follow here. In addition, there is no help file on the machine design in 2D applications. This feature is not contained by what to do. Help files contain brief information.

- **Moderate accuracy:**
  Preflu obtains 2.96 Nm with Ansoft results for a quarter of the designed machine and this would be 11.84 Nm for whole machine. 9.68 Nm would be found by using the analytical inputs. Tests show that the torque generated is too dependent on the rotor leakage reactance (resistance and inductance of the portion of end rings between two adjacent bars). Accordingly, rotor leakage reactance values are seen to give improper results.

- **Inadequate help menus:**
  Help files are very useful. When investigating a topic in the help files, there is no need for any program for this. This also provides a possibility to learn about unknown topics. Help files contain brief information.

Advantages of Ansys Multi Physics:

- **Adequate help menus:**
  Help files are very useful. When investigating a topic in the help files, there is no need for any program for this. This also provides a possibility to learn about unknown topics. Help files contain brief information.

- **2D and 3D applications are together:**
  This is advantageous for those who wish to design both in 2D and in 3D.

- **Opening speed of the project is high:**
  Opening speed of your project is very high.

- **Graphical performance is satisfactory:**
  Shape of magnetic flux distribution is the same for tri-shaped meshing while 1-2% change occurs in the resulting values. Magnetic flux distribution is given in Fig. 2. Tri-shaped meshing and this flux distribution are realistic. This is because the torque calculation reaches to its actual value, e.g. 8 Nm. The type of elements are specified in Ansys and all details of FEM are examined. A BH curve of the material can be completely made through “copy and paste” at a time as a text file from a file. This feature is not contained by the other two programs.

- **Very good accuracy:**
  The torque value obtained by ansys for the machine to be designed is 6.43 Nm. The actual torque value, 7.6 Nm, is a satisfactory value for a company that does not develop simulation programs specific for electrical machines such as Cedrat.
- **Solution speed is good**
  Solution speed gives rapid results concerning the generation of realistic values despite the fact that it is not a program developed for electrical machine design.

Disadvantages

- **Graphical plotting specifications are difficult.**
  Integration cannot be satisfied in plotting graphics which results in plotting that is completed in more than one stage. Since the menus of Ansys Multi Physics are inadequate, plotting graphics is a troublesome process.

- **Graphical interface is inadequate:**
  Drawing sizes should be corrected with a scale factor if they are not in meters since Ansys takes geometric sizes in meters. Assigning material properties should be performed one by one as no tree exists for this feature in the program.
  Undo and modify functionalities for the processes made before in a project saved in the program are very complex. Dynamic model mode icon in the menu should be used every time for zooming and dragging of a geometry in the graphical interface and then cancelled.

- **Electrical machines module is not available:**
  There is no electrical machine design module. Design is made by integration with conversion of an Autocad or Solidwork job.

- **Hard-to-use**
  The electromagnetic sample solution in Ansys is discussed through a very simple problem. Therefore, one will definitely have great difficulty in a real project.

- **Intensive memory and disk usage:**
  Two projects cannot be opened at a time in Ansys. Each project takes up approximately 600 MB in virtual memory and about 17 MB in active memory. Ansys occupies nearly 1 GB in the hard disk during simulation. In addition, it uses an excessive part of the memory during simulation. Simulation results of a 1.1 kW motor take up a space of 1.26 GB with the file where everything is saved. This is because one has to work at full scale.
  In conclusion, Ansys Multi Physics program is a difficult multidisciplinary program for initial design although it has rapid and superior features in several points.
D. ANSYS WORK BENCH

Ansys workbench program[20-29] is investigated and its advantages and disadvantages are given in comparison to other programs.

Advantages of Ansys Workbench[30]:

- **Adequate help menus:**
  Help files are very useful. When investigating a topic in the help files, surfing is possible within the program just as in MATLAB and no program is needed for this. This also provides the possibility to learn about unknown topics. Help files contain brief information.

- **3D applications are powerful:**
  Work bench is actually designed as 3D. This is a simplicity for those working in 3D.

- **Opening speed of the project is high:**
  Opening speed of your project is very high.

- **Graphics performance is satisfactory:**
  It has a better graphical interface compared to Ansys Multi Physics. It includes similar features to Autocad. A number of shapes can be formed easily.

Disadvantages:

- **Graphical plotting specifications are difficult.**
  Integration cannot be satisfied in plotting graphics which results in plotting being completed in more than one stage. Since the menus of Ansys Multi Physics are inadequate, plotting graphics is a troublesome process. As given in Figure 4, deterioration can be seen while getting closer to the drawing.

- **2D application is weak**
  As given in Figure 5, points that should be round are taken as flat directly in Workbench. 2D fields generated by Ansys Multi Physics cannot be generated in Work bench. Here, in order to make surfaces from sketches, the shape should be drawn in work bench by proceeding on the shape, and thus generating new construction points. However, this is difficult for a complex shape such as an asynchronous machine. As can be seen from Figure 6, the appearance of strange arrows with 3D because of this process indicates that 2D application has failed.
  After defining the two axis, missing or additional fields/areas should be removed or merged one by one, as can be seen from Figure 7. Although the angle between 28 rotor slots of our machine is 12.857°, a close fit is ensured on the axis while this cannot be provided on other points (Figure 8).

- **Graphical performance is low:**
Total graphical performance decreases as the number of defined surfaces increases even during study in 2D. As can be seen from Figure 10, the geometric shape made in multiphysics and imported in 3D gives face-face inconsistency error.

- **Electrical machines module is not available:**
  The fact that workbench cannot be fully integrated with sat files imported from Autocad is a huge deficiency. Although it has satisfactory specifications, workbench is not useful for electrical machines. At minimum the generation of cores of asynchronous machine is three to four times more difficult due to the Autocad integration problem.

- **Hard-to-use**
  Despite the fact that the Workbench in Ansys provides some convenience for Mechanical engineering activities, obtaining geometries and design creation is difficult for most designers. Most of the conveniences offered by Autocad is not available for lines in Workbench. The pattern command corresponding to polar and angular array command, which is indispensable for electrical machine designers, should be improved.

- **Intensive memory and disk usage:**
  Workbench requires a memory of 2 GB (650 MB ram + virtual memory) for our 3D project shows that the program is definitely a memory monster.

As a result, workbench is considered to be a hard-to-use program for electrical machine designers (even geometry construction is difficult) although it has a handy interface.
Fig. 9 The slipping of the regions of rotor bars after pattern process. Notice the location on axis.

**TABLE III**

**COMPARISON OF TORQUE VALUES (NM)**

<table>
<thead>
<tr>
<th>Torque Type</th>
<th>Reluctance</th>
<th>Mechanic</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>-</td>
<td>7,7</td>
<td>-</td>
</tr>
<tr>
<td>Analytic</td>
<td>-</td>
<td>7,6</td>
<td>98 %</td>
</tr>
<tr>
<td>Ansoft / Maxwell</td>
<td>5,53</td>
<td>-</td>
<td>72 %</td>
</tr>
<tr>
<td>Cedrat / Preflu</td>
<td>9,68</td>
<td>-</td>
<td>78 %</td>
</tr>
<tr>
<td>Ansys / multiphysics (quadratic mesh)</td>
<td>6,44</td>
<td>-</td>
<td>84 %</td>
</tr>
<tr>
<td>Ansys / multiphysics (tri-shaped mesh)</td>
<td>8,0</td>
<td>-</td>
<td>96 %</td>
</tr>
</tbody>
</table>

Fig. 10. 3D geometry in Workbench after the import process

**Fig. 11.** Workbench errors in 3D geometry after import process.

**TABLE IV**

**COMPARISON OF FEM SOFTWARE PACKAGES**

<table>
<thead>
<tr>
<th>Software</th>
<th>Version</th>
<th>Usage</th>
<th>Electric Machinery Module</th>
<th>Auto CAD file integration</th>
<th>Graphic Performance</th>
<th>Memory / Disk performance</th>
<th>Overall performance</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ansoft / Maxwell</td>
<td>2.6 / 11.1</td>
<td>Easy</td>
<td>Exist</td>
<td>Poor</td>
<td>Very Good</td>
<td>Good</td>
<td>Good</td>
<td>Average</td>
</tr>
<tr>
<td>Cedrat / Preflu</td>
<td>10.3.2</td>
<td>Difficult</td>
<td>Exist</td>
<td>-</td>
<td>Good</td>
<td>Average</td>
<td>Good</td>
<td>Average</td>
</tr>
<tr>
<td>Ansys / multiphysics</td>
<td>11</td>
<td>Hard</td>
<td>No</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Good</td>
<td>Very Good</td>
<td>Very Good</td>
</tr>
<tr>
<td>Ansys / Workbench</td>
<td>11</td>
<td>Average</td>
<td>No</td>
<td>Good</td>
<td>Bad</td>
<td>Poor</td>
<td>Poor</td>
<td>-</td>
</tr>
</tbody>
</table>
III. CONCLUSION
As can be seen from Figure 2a and 2b, the magnetic flux line distribution is similar between Ansoft and Ansys since both Pittsburg companies work together. In addition, a complete symmetry is observed in each simulation while it is not observed in the diagram of Cedrat. This is because armature reaction may also be taken into account with Cedrat. As magnetic flux lines cannot be perfectly symmetrical at this point due to the armature reaction, it can be considered that Cedrat is one-step ahead of the others. The reason why Cedrat’s geometry/drawing appears more realistic with respect to the magnetic flux density distributions may be the fact that Cedrat takes realistic windings values by taking the number of turns into consideration. Magnetic flux density distributions are not exactly true values since the excitation parameter is entered as area-based like A/m² in the other two programs. Based on the torque values given in Table 3 Ansys multi-physics is better than the others. Ansoft shows brilliant performance with respect to ease of use according to Table 4. The Ansys-Ansoft partnership gives clues that the two companies will be able to reach a better position in the future. The subject of which parameters would be accepted as criteria with respect to which program to be used in terms of engineering problems is a controversial point; however it can be considered that Ansys multi-physics is the best if torque values are considered as the most important factors for electrical machines. The fact that Cedrat is able to make mechanical torque calculation is considered a nice feature. Cedrat may be in a very important position in the long term with respect to electrical machines. However, it should give more realistic results for the torque calculation. Ansys multi-physics is seen as being unrivaled regarding multidisciplinary applications. However, its graphical interface needs a lot of improvement. The compatibility of multi-physics with Auto CAD and the closeness of torque values to realistic values stand out as a big advantage although it does not have any electrical machines module. An electrical machines module is available in Ansys and this makes its usage exclusive. Ansys Workbench should get technical support from Ansoft Company in order to eliminate the deficiencies in graphical interface. Electric machines designers cannot choose any software package in its present condition.

In conclusion, Ansoft / Maxwell is a convenient choice for junior engineers using a FEM software package for the first time. For those who desire to achieve more realistic results, Cedrat would be suitable with its superior electrical machines module and outstanding performance. Due to the fact that an electrical machine that will be manufactured commercially must be analyzed mechanically, structurally and with respect to cooling and viscosity when needed. Ansys multi physics which is very successful in achieving realistic results and unrivaled in multidisciplinary applications should be the first choice for professional engineers although it doesn’t have the features for providing great convenience such as in Ansoft and Cedrat and it is hard-to-use.

REFERENCES


Comparison of two different Power Controllers for Grid Tied Distributed Generation Systems

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Abstract—In this study, modelling and simulation studies of DG based fuel cell (FC) and solar cell (SC), connected to the common direct current (DC) bus system to provide energy for various loads. In order to synchronising of energy sources with grid, using three-phase phase locked loop (PLL) technique based park transformation which is one of the most common methods in literature. Power control methods based dq/abc synchronous reference frame (SRF) or proportional resonant (PR) are used in the DG systems. The performances of two controllers are discussed in this paper. Simulation results are obtained for various scenarios at the designed and created simulation model of DG+Grid+Load system. The system is modeled and simulated by using PSCAD/EMTDC software package.

Keywords— Distributed Generation, Renewable Energy Sources, PLL, Synchronous Reference Frame, PR controller

I. INTRODUCTION

Nowadays, environmental issues and growing demand for lower cost electricity with reliability and security, eventuate in an increased use of small electrical power generation located close to end users which are called distributed generation (DG). There is an increasing use of renewable power sources (RES) in DG systems because the growing demands for electrical energy [1]-[20]. The DG systems utilize RES, such as solar cells, fuel cells, wind turbines and micro turbines [2]. Grid connected inverters as one of the most importantly parts in DG systems, their current and power loop controllers are always the investigated [4].

In The grid tied DG systems, should be carefully designed and controlled in order to get an optimal power under fault conditions [21]. The reason to apply PR in DG system design is to eliminate steady-state error [16]. The traditional Proportional Integral (PI) controller in abc/dq- synchronous reference frame (SRF) is the common solution to solve this problem. But the complexity of displacement the ac SRF back to dc SRF where the PI controller can be used is also brought into the control system design. In this case, a transformed regulator known as PR controller is preferred considering the advantage of avoiding modulation and demodulation process in abc/dq-SRF. That is because PR controller is to transform the dc type regulator network into an equivalent ac regulator, which could directly achieve zero steady-state error in stationary frame [14]. Moreover, PR controllers are used in DG systems due to their superior behaviour over the traditional PI controllers, when filtering sinusoidal signals. Due to PR controller could achieve a very high gain around the given resonance frequency, thus being capable to eliminate the steady-state error when this controller tracking sinusoidal reference, which could be suitable for the using of stationary reference frame control strategy. The advantages of the Proportional Resonant (PR) controller in opposition to PI+ dq/abc synchronous reference frame controller are a less complexity of the control structure and a good capability to compensate harmonics. Compared with Proportional Integral + synchronous reference frame (PI+SRF) controller, the PR controller eliminates abc-to-dq and dq-to-abc frame transformations which significantly reduces computation burden and PLL errors. However PI+SRF controller could improve the dynamic response to power change and unbalanced faults [4]-[5].

In this paper, DG system based on RES, such as characteristic of fuel cell and solar cell with maximum power point (MPP) are investigated. It is analysed the performances of PI+SRF (abc/dq) and PR based Power Controllers in grid tied distributed generation systems. Reliable performances of controllers under grid voltage drop and references power change cases are discussed. Simulation results are provided to illustrate the effectiveness of the proposed system. The validity of proposed topology and control methods are verified with PSCAD/EMTDC software package.

II. DG SYSTEM CONFIGURATION

The implemented DG system in PSCAD/EMTDC is shown in Fig. 1 where FC/Solar cell (SC) combined form is the main form of DG system. DG system is connected to DC bus system. Voltage source inverter (VSI) connected AC side with grid and loads. The output voltage from the inverter contains high order harmonics which must be eliminated and thus, a low LC filter and PR current controller are used to reduce the harmonic contents in the phase current and the output voltage. The technical details of each part of the DG system are given in the following subsections.
Fuel Cell System

The stack voltage and the reference power are determined the reference current which is determined for the fuel cell stack current in eq. (2) and (3). The fuel flow is proportional to the stack current. The dynamic model of the FC stack is presented based its electrochemical and thermodynamic characteristics and emphasis on the FC terminal electrical characteristics [11]-[12]. The partial pressure of hydrogen, oxygen and water are determined using the flow rates of hydrogen and oxygen. The stack current and pressure of gases affect the stack voltage [13]. A simulation model is developed for the FC in PSCAD/EMTDC based on the dynamic FC stack. The output voltage of the stack is given by the Nernst equation. The ohmic loss of the stack results from the resistance of the electrodes and to the resistance of the flow of oxygen ions through the electrolyte.

\[ E_0 = N_0 \left( E_0 + \frac{R \cdot T}{2F} \ln \left( \frac{P_{H_2} \cdot P_{O_2}^{0.5}}{P_{H_2O}} \right) \right) - r_{\text{ohmic}} \cdot I_{fc} \]  

(1)

\[ I_{\text{ref}} = \frac{P_{\text{ref}}}{V_{fc}} \]  

(2)

\[ I_{fc} = \frac{I_{\text{ref}}}{1 + \tau_e \cdot S} \]  

(3)

The power output of fuel cell system is the product of stack current and voltage;

\[ P_{fc} = N_0 \cdot V_{fc} \cdot I_{fc} \]  

(4)

Variable DC load tied to the FC system. Fig. 5 shows modelled the fuel cell system in PSCAD/EMTDC under variable DC loads. The fuel cell stacks current and power increase and decrease with the DC load change. However, with the load change, boost converter output voltage (DC bus voltage) is constant.
b. Solar Cell

Fig. 3 shows a simple equivalent circuit of a SC. The current source which is driven by sunlight is connected with a real diode in parallel. In this case, SC presents a p-n junction characteristic of the real diode. The forward current could flow through the diode from p-side to n-side with little loss. However, if the current flows in reverse direction, only little reverse saturation current could get through [14].

\[
I_{cell} = I_{ph}(1 + I_0(T - 273.15)) - I_o \left( e^{\frac{q(V_{sc} + I R_s)}{n k T}} - 1 \right) - \frac{(V_{sc} + I R_s)}{R_{sh}}
\]  

(5)

In this paper, grid tied SC system is modelled and simulated in PSCAD/EMTDC software under various load, radiation and temperature. MPP incremental conductance algorithm is implemented in PSCAD/EMTDC in order to get the maximum output power for any given solar irradiation and temperature. Fig. 4 shows the characteristic (I-V and P-V) of SC and it pointed MPP.
provide SRF-PLL with PI+SRF and PR current controller can enforce orthogonal voltage (Vq) tracking grid voltage with grid voltage drop (30 %) successfully.

**b. abc/dq-SRF**

PI controller cannot eliminate steady-state error for the alternative current (AC) control as in three-phase grid tied DG system. To solve this problem, a mathematical transformation abc/dq-SRF has been universally applied system. Abc/dq-SRF transformation is short for direct quadrature zero transformation which is usually applied to the three-phase AC circuit analysis. The main reason to apply this method is for simplification of analysis. In balanced three-phase systems, abc/dq-SRF transformation transform three AC quantities to two directive current (DC) quantities into two-phase frame such as direct axis (d) and quadrature axis (q) [17]. Simplified calculations can then be carried out on these imaginary DC quantities. In this case, the application of dq0 transformation not only reduces the complexity of system analysis but also provides an available DC operation condition for PI controller [14].

Park’s transformation—which is given in eq. (6) and (7):

\[
I_{dq0} = \begin{bmatrix}
\cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta + \frac{2\pi}{3}) \\
\sin(\theta) & -\sin(\theta - \frac{2\pi}{3}) & -\sin(\theta + \frac{2\pi}{3}) \\
\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2}
\end{bmatrix}
I_{abc}
\]  

\[
I_{abc} = \begin{bmatrix}
\cos(\theta) & -\sin(\theta) & \sqrt{2} \\
\cos(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{2\pi}{3}) & \sqrt{2} \\
\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2}
\end{bmatrix}
I_{dq0}
\]

Modelled and simulated the PI+SRF controller based park transformation in PSCAD/EMTDC are given in Fig.7.
c. The Proportional Resonant (PR) Current Controller

Although its popularity, a PI controller is not able to track a sinusoidal reference without the steady-state error (magnitude and phase). PI controller such as lack of tracking a sinusoidal reference with zero steady-state error and poor disturbance rejection capability [6]. To overcome the mentioned problems of conventional PI controllers in SRF, PR current controller is proposed. The PR controller provides a high gain and zero steady-state error. Besides its simplicity, the system dynamics is almost not affected by the harmonic compensation terms. However, the PR controller is difficult to implement in reality. It has two problems. Firstly, the infinite gain introduced by a PR controller leads to an infinite quality factor which cannot be achieved in an analog or a digital system processor (DSP). Secondly, the gain of the PR controller is much decreased at other frequencies and it is not adequate to eliminate harmonic influence caused by grid voltage harmonics [7]-[8].

Fig. 8 shows that $\omega_o$ is grid fundamental angular frequency and $k_i$ is a constant which is carefully selected to shift the controller’s magnitude response vertically [6].

$$G(s) = \frac{k_p}{s^2 + 2w_c s + \omega_o^2}$$ (8)

And $k_p$ and $k_i$ are the proportional and integral gains of PR controller respectively, and $\omega_c$ is cut-off angular frequency. The transfer function shows a no-ideal PR controller which has lower gain and wider bandwidth than ideal PR controller at the resonant frequency [6]. The power/current controller of the DG system with PR controller is illustrated in Fig. 9.

---

Fig. 7 Synchronous Reference Frame with PI Control Strategy.

Fig. 8 PR Current Controller Block Diagram [10]
PR gain is finite, but it is relatively high for enforcing a small steady-state error. The controller's bandwidth can be widened by setting \( \omega_c \) suitably, which helps to reduce sensitivity towards slight frequency variations [9].

IV. SIMULATION RESULTS

To better understand the performances of the controllers and using main parameters in DG system are given in Table 1 and 2. Their graphics and values are given at the same scale in Fig. 9 and 10 for easily comparing the controllers.

Table 1. Main parameters DG system

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>R filter</td>
<td>0.005 ( \Omega )</td>
</tr>
<tr>
<td>L filter</td>
<td>0.5 [mH]</td>
</tr>
<tr>
<td>C filter</td>
<td>16 [( \mu )F]</td>
</tr>
<tr>
<td>DC bus voltage</td>
<td>800 V</td>
</tr>
<tr>
<td>Grid voltage</td>
<td>380 ( V_{L1} ), rms</td>
</tr>
</tbody>
</table>

In this case 1, reference power step changes from 1 p.u. to 0.8 p.u. at 1.1 s and the output performance of controllers can be seen in Fig. 10. The reference value of real power and reactive power step change simultaneously at both 1.1 sec, the corresponding output performance of the system with given reference values are shown in Fig. 10. As one can see from Fig. 11, the system keeps stable under step-change conditions. However, the output power of PI+SRF controller is able to track the reference values well in less than 0.015 s, which proves a good dynamic performance than PR current controller (0.125 sec.). In this case 2, when reference power step changes at 1 s, orthogonal currents with PI+SRF (stable with 0.1 sec.) have a good dynamic performance better than PR current controller (stable with 0.175 sec.) in Fig 11.

Fig. 9 DG system with PR Power Controllers

Case 1:

Fig. 10 Power of system with reference power change
Case 2:

![Orthogonal current with reference power change](image)

Fig. 11 Orthogonal current with reference power change

Table 2. Performances of Controllers

<table>
<thead>
<tr>
<th>Controllers</th>
<th>PI+SRF</th>
<th>PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response of reference</td>
<td>0.015 sec</td>
<td>0.125 sec</td>
</tr>
<tr>
<td>Orthogonal currents</td>
<td>0.01 sec</td>
<td>0.175 sec</td>
</tr>
</tbody>
</table>

V. CONCLUSION

DG system based on RES provides a good substitute to the centralised power generation systems which consumes fossil fuels and has imposed several problems on the environment. The most important aspect of DG systems is their proper control methods in order to ensure sinusoidal current injection into the grid. For this proper synchronization with the grid is SRF-PLL. This paper presents PI+SRF and PR based power controllers for grid tied DG systems. In this paper, dynamic performances of control methods are discussed.

REFERENCES


A study on parameters of Photonic Crystal Fiber Modes

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Abstract—Optical fibers which have been in human life for 30-40 years, were used in long haul telecommunication links in the first decade. But today, fiber optic is used every distance of communications. Beside communications, fiber optic Technologies are spreading out in optical sensor technologies and networks, industry and medical in today. Classical optical fibers is standardized and has come to limit of refinement. As a new generation of optical fiber, with feature of very flexible design, photonic crystal fibers (PCF) are promising new horizons. PCFs are designed as endlessly single mod fiber in very wide range of wavelengths. Dispersion, birefringence and nonlinearity can be obtained in desired characters by changing geometrical parameters of PCFs.

In this simulation study, fundamental and high order core modes, cladding modes, fundamental space filling mode (FSM) and high order space filling modes were found. Effective refractive indices of the modes were calculated.

Keywords—Fiber optic, Photonic Crystal Fiber, Fiber optic sensor, Effective refractive index

I. INTRODUCTION

Photonic crystal fibers (PCF) are new generation fiber optic waveguides which have different structures and features from classical fiber optics[1,2]. PCFs are produced from a single material. They have air holes around core which are parallel to core and run along the fiber. Air holes are positioned in many rings around core. PCFs with various geometric features (hole diameter, distance of holes, number of rings, etc.) of cross section show different guiding features. PCFs have many advantages over classical fibers. PCFs have wide range of wavelength of single mod guidance, dispersion, non-linearity and birefringence control and endurances to bending[1-7].

PCFs have two dimensions periodicity. At least one characteristic dimension is about to magnitude of wavelength of guided light[8]. PCFs are called as crystal fibers, holey fibers and microstructure optical fibers (MOF), too. Since air holes arrayed in two dimensions in periodic structure, PCFs is a special tip of MOFs[9]. Core of PCF may be solid or air hole (Fig. 1) [10 -13]. Photonic crystal fibers with air hole core is also called hollow core fibers.

Guided light propagate with different mechanism in 2 holey fibers which have different basic structures. In fibers with solid core, light propagate with modified total internal reflection. Cladding that is the section with air holes shows lower refraction index than core and provides guiding of light. That is also called index guiding. In hollow core fibers, light is guided with principle of photonic band gap. Light with some wave length does not propagate in the fiber. Guidance of light in the fiber occurs in certain bands[14].

II. MODES OF PCF

In core and cladding of PCFs, various modes occur due to guidance conditions determined with parameters of geometry and material of PCF and light. A number of modelling methods have been offered to analyse modes, mode properties and propagation characteristics of PCFs[15-23]. Considerable modelling methods are effective-index, the plane-wave expansion, localized basis function, finite-element, finite difference, finite difference time domain (FDTD), beam propagation and multipole method.

Modelling and after modelling processes give patterns of modes, effective refractive indices of modes, mode areas, confinement losses, dispersion characteristics. Effective refractive indices of modes are very important parameters for especially fiber optic sensor systems. Cladding modes are very critical for PCF sensor in respect to analyse interaction liquid or/and gas materials in holes of the PCFs and guided light [24,25].

Fundamental Space Filling Mode (FSM), is fundamental mode which propagates in cladding[3]. FSM is used effective cladding index and the mode with highest refractive index in cladding[26].

\[
\beta_{FSM} \quad \text{and} \quad \beta_{FSM} \text{are supposed to effective refractive index and propagation constant of FSM, respectively.}
\]

\[
\beta_{FSM} = \beta_{FSM} k_0
\]

\[
\beta_{FSM} \quad \text{is valid for index-guided mode in core. Refraction index of silica glass in core of PCF is up to } n_{co} \text{ This inequality is valid;}
\]

\[
n_{co} > n_{eff} = \beta/k_0 > n_{FSM}
\]

Fig. 1 Holey fibers: a) Solid core PCF[28], b) Hollow core fiber [6].
Numerical and analytical methods can be used for calculation and analysis of FSM. Analytical method is two types as scalar and vector methods. In a study, it was seen that results of vector methods was better matched to results of numerical method[26]. Guided modes in section of silica glass out of rings of holes are admitted as FSM. This section is called as FSM layer[27].

III. RESULTS OF SIMULATIONS
Simulation study was implemented by using finite element method (FEM) for PCF of NKT Photonics LMA-20. Properties of LMA-20: d = 6 (µm), p = 12.8 (µm), number of hexagonal rings = 6, outer cladding diameter = 230 (µm). Guided modes and electric field patterns of modes have been obtained. Effective refractive indices (n_{eff}) of the modes have been calculated in those simulations. It was seen that single mode (LP_{01}) guided in core of PCF. Furthermore, low order modes and their effective refractive indices were obtained in cladding of the PCF.

Some modes have been detected at FSM layer in the simulation of large mode area PCF (LMA-20). In FSM layer modes, maximum n_{eff} of PCF modes have been observed.

The simulation study have been implemented for 560-2300nm range of wavelength.

Modes of core, cladding and FSM layer which have found by means of simulations for wavelength of 600 nm are shown in Fig. 2. In this figure, some prominent low order modes are taken part.

Effective refractive indices of the modes have been also obtained over simulations. Graphic of effective refractive indices verse wavelengths have been sketched in matlab. The graphic is shown in Fig. 3.
Effective refractive indices of core, cladding and FSM were obtained. For this 0.45 μm of wavelength range, guided mode LMA based on FEM, one of the PCF modelling method, is used. Fig 3. Variations of effective refractive indices verse wavelengths of guided modes of PCF LMA-20.

REFERENCES


Offline Vehicle Tracking and Visualizing on Digital Maps

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Abstract— Tracking mobile objects has always attracted people’s interest and over time it has become a necessity to keep records of them. Various solutions have been developed to meet this need. In particular, the development of GPS and digital mapping system has contributed greatly to this solutions. The developed methods can be divided into two main categories as online and offline systems. Although the online systems provide advanced features, production and operating costs are quite high and have regular expenses. In this study, we propose a microcontroller based offline vehicle tracking system. The proposed system offers a practical, low cost and high capacity approach for vehicle tracking systems. The proposed system calculates the vehicle’s position and speed according to the signals gathered from GPS satellites and records them to an SD card continuously. The stored data, then, can be transferred to a computer easily whenever needed and the routes that the vehicle followed can be tracked on a digital map using google earth. Besides, some visualization techniques like coloring routes with regards to time or speed intervals can be used for advanced analyses of the data. The proposed system allows the GPS data to be recorded as long as 3 months on a 4 GB SD card continuously.

Keywords— GPS; Digital Map; Offline Tracking; Vehicle Tracking; GPS Data Visualizing

I. INTRODUCTION

The free, open, and dependable nature of GPS has led to the development of hundreds of applications in such areas as marine, aviation, agriculture, environment, space, surveying, mapping, public safety, disaster relief, recreation, timing, rail, roads and highways. Although tracking systems was first developed for fleet management and shipping systems, today it is used in many areas of daily life [1], [2].

Vehicle tracking systems used today are generally online systems. That is, the information like location and speed of the vehicle are sent to a management center in real time. Online systems depend on GPRS or SMS technology to communicate with a management center or a central server. Despite the many advantages of this system, they have some regular expenses beside the initial setup costs. These expenses involves monthly subscription fee per vehicle for GPRS services, server and management center operating and maintenance fees, domain name fees and server hosting costs. Moreover, if these services are not owned by self, it is needed to subscribe such services and pay subscription fee monthly for each vehicle to be tracked.

In case of GPRS or generally internet connection loss, there might be data loss if the device on the vehicle does not have a local storage unit.

There might some cases that real time tracking of the vehicles is not essential and having past records might be sufficient. For example, for a school bus debates about following route, timing and obeying speed limits can be illuminated by examining previous records. Similarly, a company can use recorded past data to check its vehicles routes, departure and arrival times and to estimate amount of fuel consumption. This data may also be used as evidence in case of accident or a crime. For such cases, there is no need for real time or online tracking systems and having just an offline tracking record is sufficient.

In this study, a practical and low cost solution is proposed as an alternative to real time or online tracking systems. For this purpose, an offline tracking system which records the data received from GPS satellites to a pluggable SD card is developed. Then, the recorded data can be transferred easily to any computer when needed and can be monitored on a digital map using google earth. Since the GPS data is recorded directly on SD card as standard NMEA format, there is not a dependency to any special or commercial software to monitor the data on a digital map. Any software able to monitor GPS data can be used. In this study google earth is used to visualize the users route on digital maps.

II. GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS) is a satellite system that provides users with positioning, navigation, and timing information. The GPS system was created by US. Department of Defense and has been available to civilians since 1980. Generally, it is used to track and navigate the mobile objects.

The GPS system consists of three segments: The space segment, the control segment, and the user segment.

- The space segment basically consists of 24 satellites that travel around the earth two times a day. The arrangements of the satellites on 6 planes allow at least four of them to be visible by receivers from any point on the Earth.
• The control segment consists of ground stations which track the satellites, monitor their transmissions and send command and data to keep them in their orbits.
• The user segment is composed of military and civilian applications. The military services use L2 frequency and have a more precise positioning and timing capability than the civilians. [3], [4]

III. SYSTEM DESIGN AND IMPLEMENTATION

The designed system is described in detail in this section. Block diagram of the designed offline tracking system is shown in Figure 1. The three main parts of the system are GPS module, microcontroller and data storage. The GPS receiver module’s function is to calculate the vehicle position according to information received from GPS satellites. The microcontroller processes the data obtained from GPS receiver module and selects desired NMEA sentences. This data is stored to a pluggable SD card. Whenever needed, SD card can be plugged in a computer to monitor the data on a digital map. All components in the circuit require a 3.3V voltage source. The device includes a voltage regulator on board and vehicle’s battery or a separate battery can be used as a power supply.

GPS module transfers data using NMEA 0183 standard. Although there would be device specific communication protocols, NMEA is a standard protocol supported by all GPS receivers. There are several NMEA sentences as GGA, GLL, GSA, GSV, RMC and VTG. These sentences include some common and some sentence specific information. [4]

In this study, RMC sentence is used because it includes all the information required for this application. A sample RMC sentence and message format is as follows:

$GPRMC,053740.000,A,2503.6319,N,12136.0099,E,2.69,79.65,100106,.,A*53

Description of the sample RMC sentence is seen in Table 1.

TABLE I
DESCRIPTION OF AN EXAMPLE RMC SENTENCE

<table>
<thead>
<tr>
<th>Name</th>
<th>Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message ID</td>
<td>$GPRMC</td>
<td>RMC protocol header</td>
</tr>
<tr>
<td>UTC Time</td>
<td>053740.000</td>
<td>$hhmmss.sss</td>
</tr>
<tr>
<td>Status</td>
<td>A</td>
<td>A=data valid or V=data not valid</td>
</tr>
<tr>
<td>Latitude</td>
<td>2503.6319</td>
<td>dddmm.mmmm</td>
</tr>
<tr>
<td>N/S Indicator</td>
<td>N</td>
<td>N=north or S=south</td>
</tr>
<tr>
<td>Longitude</td>
<td>12136.0099</td>
<td>dddmm.mmmm</td>
</tr>
<tr>
<td>E/W Indicator</td>
<td>E</td>
<td>E=east or W=west</td>
</tr>
<tr>
<td>Speed over ground</td>
<td>2.69</td>
<td>TRUE</td>
</tr>
<tr>
<td>Course over ground</td>
<td>79.65</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>100106</td>
<td>ddmmmyy</td>
</tr>
<tr>
<td>Magnetic Variation</td>
<td>Not Available, Null Field</td>
<td></td>
</tr>
<tr>
<td>Variation Sense</td>
<td>E=East or W=West (Not Shown)</td>
<td></td>
</tr>
<tr>
<td>Mode</td>
<td>A</td>
<td>A=autonomous, D=DGPS, E=DR</td>
</tr>
<tr>
<td>Checksum</td>
<td>*53</td>
<td>End of message termination</td>
</tr>
</tbody>
</table>

A. GPS Module

The GPS module is used to get the current position and speed of vehicle. In this study, LINX RXM-GPS-SR receiver module (shown in Figure 2) is used for getting latitude, longitude, altitude, date and time information. Small dimensions (25.2mm-12.4mm-11.9mm) and low cost of this device is the major reasons for selecting the module. It has an integrated antenna and direct serial interface to communicate with host device. The update rate of the module is 1Hz and position accuracy is less than 10 meters. The module is based on the SiRFstar III low power chipset. The module’s high-performance RF architecture allows it to receive GPS signals that are as low as -159dBm. [4]

B. Microcontroller

In this project, PIC18F4620 microcontroller is used. PIC18F4620 has built in UART and SPI hardware for serial communication and has a wide range of operating voltage (2-5.5V) [5]. In this study, both GPS receiver and SD card module requires 3.3V power supply. A microcontroller capable of operating at 3.3V simplifies the circuit design and reduces the number of power supplies required.

The microcontroller has two main tasks. First one is to get NMEA sentences from the GPS receiver. The microcontroller communicates with GPS receiver through RS232 serial communication protocol. The GPS receiver sends 6 different NMEA sentences every second. Microcontroller receives all these sentences and selects the desired ones.

The second task of the microcontroller is to store the selected NMEA sentences to an SD card. The microcontroller uses build in SPI hardware to communicate with SD card. The data is written to a text file in a FAT formatted SD card.

Fig 1. Block diagram of the designed offline vehicle tracking system

Fig 2. LINX RXM-GPS-SR receiver module
Flowchart of the microcontroller software is seen in Figure 3. Microcontroller initializes the SPI and UART communication ports and checks availability of the SD card. If card is not present, led flashes at 2 Hz to warn the user. If the card is available, microcontroller reads the GPS data over UART port in accordance with the flowchart in Figure 4. Flowchart of subroutine running in the microcontroller for selecting NMEA sentence and recording data to SD card is shown in Figure 4. The software is prepared using MikroC compiler. [6]

C. Storage Unit (SD Card)

Secure Digital (SD) is a non-volatile memory card format developed by the SD Card Association (SDA) for use in portable devices. SD cards are available in a wide range of capacity and speed classes. SD cards are preferred due to their high capacity and small size. SD cards used in this project needs to be formatted as FAT or FAT32 file system. While FAT file system is used in SD cards up to 2 GB capacity, FAT32 file system is used in SD cards up to 32 GB capacity [7], [8].

D. Digital Maps

Digital maps are becoming increasingly widespread. Especially, the development of the GPS system has contributed greatly to the development and widen the usage areas of digital maps. Most of the information that comprise digital maps is satellite images as well as street level information. Digital maps has the advantage of being updated through synchronization with updates from company servers [9].

There are many digital maps used today. But most well-known and widely used maps are google map and google earth. Google maps are mostly used for navigational purposes while google earth is used exploring the world in a more detailed 3D maps. Although there are many common features between google earth and google maps, the main difference is that google earth is an desktop application and google maps is an online web application. Google earth is used in this study, since it can examine the GPS data directly.

IV. RESULTS AND DISCUSSION

The prototype device prepared for offline tracking is given in Figure 5. The dimensions of the device are 45 mm x 65 mm x 25 mm.

Fig 3. Flowchart of main program on microcontroller

Fig 4. Flowchart of NMEA sentence selection subroutine

Fig 5. The prototype of the designed system
In order to test the designed system, the device is put into a vehicle and two different routes were followed in Ankara. Meanwhile, the device collected and recorded the GPS data to an SD card. The obtained data were transferred to a computer just by simply copying the GPS data file and the paths followed are imported to google earth and displayed on a digital map (Figure 6).

Various digital map types can be used to monitor and analyze the GPS data. Google earth is a simple and easy to use digital map monitoring tool and can be used to display tracking data like followed route, speed of the vehicle, time and date without need to any conversion. A digital map image as shown in Figure 6 is generated by simply importing the row data to google earth.

Displaying row data on google earth is easy and practical, but in some cases, it might be necessary to make it more user friendly and understandable. For example, it might be necessary to examine whether a school bus exceeded speed limits, followed its route, or arrived to children’s home on time. In these cases, coloring the routes according to speed or time intervals might be useful. It is possible to convert row GPS data to KML format and display it in a better understandable manner. KML (Keyhole Markup Language) is used for formatting 2-D and 3-D geodata for display in earth browsers.

In this study, in order to make detailed analyses of GPS data, GPS Visualizer is used to convert GPS data to KML format and GPS data is colored according to time and speed intervals.

By organizing KML file using GPS Visualizer, the tracked route of the vehicle can be highlighted in different colors according to time or speed intervals [10]. In Figure 7, the followed routes are drawn according to time intervals. In the figure, red, yellow, green, blue and purple points represent the time interval between 12.05-13.30, 13.30-14.45, 14.45-16.21 and 16.21-17.46. For school bus example, highlighting routes according to time intervals enables observers to easily determine the location of the school bus in a specific time interval. Besides, the observer can mark on a data point in order to check speed and location of the user in terms of latitude and longitude.

Another way for detailed analysis of the followed route is visualizing the data in terms of speed of the vehicle. In this visualizing type, data is highlighted in different colors according to speed intervals. In Figure 8, the followed routes are colored according to vehicle’s speed. Five different speed intervals are highlighted in five different colors. The speed intervals can be set easily by observers. Considering school buses, compliance with speed limits is one of the most important issues. This visualizing technique enables observers easily determine the routes at which the speed limits are exceeded by the drivers.

Another important issue with the offline vehicle tracking systems is data storage capacity. Data storage capacity of the designed system is depends on the SD card used. It is a removable media and can be replaced with a higher capacity SD card according to the needs. By using a 4 GB SD card in this study, the system is able to save 6 types of NMEA sentences data for at least 3 months.
V. CONCLUSIONS

Safety is becoming an important requirement in growing and crowded cities. Tracking systems are getting essential tools for traffic safety. Especially for safety and deterrence purposes continuous recording of vehicles movement is a requirement and offline tracking systems are useful and suitable tools for many application. In this study, an offline vehicle tracking system was designed and implemented that can be used to record continuously the movement times, speeds and routes of vehicles. In this context, a circuit was designed to save the GPS data to a storage unit and the routes of the tracked vehicle were visualized on Google Earth.

Offline vehicle tracking systems offer low cost and convenient solution for situations where real time monitoring is not vital. Besides, the proposed system has several advantages such as low hardware costs, high storage capacity. Moreover, the system does not need constant periodic fees.

Presence of such a tracking system on the car will also create a deterrence on the driver. School buses can be thought as good candidate users of this project. In this way, in an unexpected situation, observers easily check whether or not the drivers changed the predetermined route, or the drivers exceeded the speed limits.

In terms of system cost, the proposed offline tracking system has superior advantage compared to online tracking systems. Since map viewing application is free, cost of the system only consists of hardware components. Besides, there is no software fee or update fees. Moreover, it does not occur additional expenses for SMS or internet connection.

Because of small dimensions, low power requirements, and high storage capacity, the designed vehicle tracking system can be adapted to other objects or living things, such as cyclists, pedestrians or animals in the nature.

The proposed system can incorporate with the existing navigation systems as an additional feature. Moreover, the system can be implemented to the vehicles during their production. Dimensions of the module can be minimized by using micro SD cards and surface mount components.

REFERENCES

Abstract—This paper presents a practical comparison study on the speed estimation methods for induction motors by using Direct Torque Control in terms of their estimation performances especially at startup. Simulation and experimental test studies on various operations characteristics are achieved and presented together with the evaluations. The estimation techniques are compared in terms of their capabilities of speed tracking and sensitivities for each operation condition. It is concluded that at startup operation and in steady state behavior, dynamic performance of Model Reference Adaptive System (MRAS) is more stable and effective than sliding mode observers and open-loop estimators. However, open-loop speed estimation method has better performance than the others. Dynamic performance of the speed estimators in DTC control algorithm are tested in a laboratory setup. System configuration includes a low cost STM32F407VG Discovery board used for the implementation of the control algorithm, there-phase power inverter which is designed for this purpose and industrial type of 11 kW induction motor.

Keywords—Speed Estimation, Sensorless Control, Direct Torque Control, AC Drives, Sliding Mode Estimator, MRAS, Open-Loop Estimator, Performance Investigation, Induction Motors.

I. INTRODUCTION

In recent years, importance of the adjustable-speed drives used in industrial and electric vehicle applications has been increased. Modern AC motor drives produced in last decades are composed of microcontrollers, electronic components, digital or analog controllers and sensors. However, many control techniques consisted of more complex algorithms based on the sensorless control system are preferred due to high prices of the sensors, their low safety operations and drawbacks of the noise effects. The enhancement in processor technologies, advanced microcontrollers have made it possible to carry out more complex control algorithms with high efficiency.

Due to avoiding of sensor drawbacks and reducing the cost of the inverters, estimation of the actual speed instead of the measurements is more available for the researchers and engineers. In literature, control algorithms designed with feedback are used generally to estimate the speed of induction motors with high accuracy [1-8]. Most of the estimation techniques work on the magnetic flux waves, such as open-loop estimators and close-loop observers used for this purpose. Speed at dynamic performance and steady-state can be calculated properly if parasitic effects are wiped away [9]. Using only motor parameters is easy way to estimate actual speed of the motor. However, the method can be applied in a limited range. In a study, a hybrid mathematical model, which sustains a low-cost proper design for the industrial applications, is presented [10-13]. Also, flux, speed and rotor time-constant can be estimated by using a sliding functions. It guaranteed an accuracy of the parameters when the difference between the actual current and the observed current is zero [14-18]. Moreover, model reference adaptive system (MRAS) based speed sensorless algorithm can be used for controlling an induction machine. In this method, a proportional-integral (PI) controller is employed in the adaption mechanism instead of pure integral because of initial problems [19-23].

In this study, some of these methods used for control of the induction motors with direct torque control (DTC) without any speed sensor, such as open-loop speed estimator, sliding mode observer based speed estimator and MRAS based speed estimator are compared with each other on various conditions. And, the results obtained by the experiments are presented and introduced a discussion on the results accompanied with the evaluations.

II. INDUCTION MACHINE MODEL

Dynamic model equations of the induction motor used in many control algorithm are given by the equations 1 to 5. The equations include not only steady state characteristics but also starting behavior. The model is represented by differential equations referred to d-q reference frame rotating at the synchronous speed with a view to simplify the analysis of three-phase circuits.

The parameters used in the equations are stator winding resistance and inductance ($R_s, L_s$), rotor bar resistance and inductance ($R_r, L_r$) and mutual inductance ($L_m$).

\[
\frac{di_s^d}{dt} = \beta \frac{1}{Tr} \lambda_s^d + \beta \omega_L \lambda_q^d - k_1 i_d + k_2 V_d \quad (1)
\]

\[
\frac{di_s^q}{dt} = \beta \frac{1}{Tr} \lambda_s^q - \beta \omega_L \lambda_d^q - k_1 i_q + k_2 V_q \quad (2)
\]
\[
\frac{d\lambda}{dt} = -\frac{1}{T_e} \lambda_s^2 - \omega_r \lambda_s \lambda_{qs} + \frac{l_m}{T_e} i_d s
\]

Switching any voltage vector considering the voltage vector table (e.g. Table. I) provides keeping the stator flux in the determined hysteresis error band corresponded with the calculated torque behavior. Each of \( V_s \) vectors represents a switching position of VSI. Voltage space vectors, switching positions and sectors are shown in Fig. 2.

\[
T_e = \frac{3P}{2} (\lambda_{dr}^2 i_{qs} - \lambda_{qr}^2 i_{ds})
\]

where,

\[
\sigma = 1 - \frac{l_m^2}{l_s l_r} \quad k_s = \frac{1}{\sigma l_s}
\]

\[
T_r = \frac{l_r}{T_r} \quad \beta = \frac{k_s l_m}{T_r}
\]

\[
k_1 = k_2 (R_s + \frac{l_m^2}{l_r T_r})
\]

III. DIRECT TORQUE CONTROL

Direct Torque Control technique called DTC is defined briefly as a proper selection of stator voltage vector and direct control of stator flux for estimation of the torque by sensing phase currents and DC bus voltage. The main idea of DTC is related with control of the stator flux and electromagnetic torques synchronously. The superiorities of the technique are less sensitive to parameter changes with respect to the other vector control methods, having quite simple algorithm and faster torque response than others. The control algorithm includes only calculating of stator parameters. Fig. 1 shows principle of the DTC algorithm.

![Fig. 1 Schema of Direct Torque Control (DTC) System](image)

**TABLE I**

| \[|\lambda|\] | \[\lambda\] | \[d\lambda\] | \[dTe\] | Region |
|---|---|---|---|---|
| 1 | V_2 | V_3 | V_4 | V_5 | V_6 | V_7 |
| 0 | V_4 | V_5 | V_6 | V_7 | V_8 | V_9 |
| -1 | V_6 | V_7 | V_8 | V_9 | V_10 | V_11 |
| 0 | V_8 | V_9 | V_10 | V_11 | V_12 | V_13 |
| -1 | V_10 | V_11 | V_12 | V_13 | V_14 | V_15 |

Voltage vector selection in the control algorithm is related to the stator fluxes behaviors, instant torque value and sector of stator flux linkage vector. Torque and flux are estimated by using instant value of the phase currents and dc voltage.

![Fig. 2 Space Vectors and sectors](image)

The aim of this paper is to show dynamic performance of the speed estimators used in DTC control algorithm. The estimation techniques are compared with each other in terms of their capabilities of speed tracking performance and sensitivities to the operation conditions.

IV. SPEED ESTIMATION METHODS IN BRIEF

Sensorless control of squirrel cage induction motor have been widely used in industry during the last decade. In the literature, many methods are introduced and investigated to estimate the actual speed of the motors and to produce the best switching for the voltage vectors.

A. Open Loop Speed Estimator

The model consists of four motor parameters; stator resistance, transient inductance, magnetizing inductance and rotor resistance referred to the stator. All other variables used in calculation are also referred to stator.

The relationship among the speed, currents and fluxes are given as follows:

\[
\omega_{mr} = \frac{\lambda_s^2}{\lambda_{dr}^2 + \lambda_{qs}^2} \frac{d\lambda_{qs}}{dt} - \omega_{slip}
\]

\[
\omega_{slip} = \frac{l_m}{T_r} (\lambda_{dr}^2 i_{qs} - \lambda_{qr}^2 i_{ds})
\]

\[
\omega_r = \omega_{mr} - \omega_{slip}
\]

B. Sliding Mode Observer Based Estimator

In this method, sliding-mode-based flux and speed estimation method are used without any speed sensor for DTC algorithm. The method includes speed, rotor time and flux estimations and current observer. Sliding-mode current observer is used to estimate the speed and rotor time constant, as shown in the equations 9 and 10.
\[
\frac{d\psi_d^s}{dt} = \beta \psi_d - k_1 i_{d}^s + k_2 V_{ds}^s
\]  \tag{9}

\[
\frac{d\psi_q^s}{dt} = \psi_q - k_1 i_{q}^s + k_2 V_{qs}^s
\]  \tag{10}

The flux used for calculating observed current is determined by production of \( u_0 \) and sign of the error selected large enough. The sliding equation provide observing the stator current components in the stationary reference frame.

\[
\psi_d = -u_0 \text{sign}(s_d)
\]  \tag{11}

\[
\psi_q = -u_0 \text{sign}(s_q)
\]  \tag{12}

where,

\[
s_d = i_{ds}^s - i_d^s
\]  \tag{13}

\[
s_q = i_{qs}^s - i_q^s
\]  \tag{14}

\[
\psi_{dq}^s = \frac{1}{\mu s + 1} \psi_{dq}
\]  \tag{15}

\[
\frac{d\lambda_{dr}^s}{dt} = -\psi_d^s + \frac{1}{t_r} i_{d}^s
\]  \tag{16}

\[
\frac{d\lambda_{qr}^s}{dt} = -\psi_q^s + \frac{1}{t_r} i_{q}^s
\]  \tag{17}

\[
\lambda = \frac{1}{i_{a}}(-\lambda_{dr}^s \psi_d + \lambda_{dr}^s \psi_q)
\]  \tag{18}

|\lambda| = -\left(\lambda_{dr}^s\right)^2 - \left(\lambda_{qr}^s\right)^2
\]  \tag{19}

C. MRAS Based Speed Estimator

In this method, the estimated speed is calculated by the reference model of the whole system, adaptive model and an adaptation mechanism. Also, measured currents and voltages in a stationary frame of reference are used in the equations.

In order to estimation of the rotor actual speed, rotor fluxes state variables are obtained from the reference model using stator currents and stator voltages and adaptive model using stator currents and the speed.

The model reference equations are written as follows:

\[
\frac{d\lambda_{dr}^s}{dt} = \frac{1}{t_r} (\psi_d^s - R_{ds} i_{ds}^s - \alpha \lambda_{dr}^s \frac{d\lambda_{dr}^s}{dt})
\]  \tag{20}

\[
\frac{d\lambda_{qr}^s}{dt} = \frac{1}{t_r} (\psi_q^s - R_{qs} i_{qs}^s - \alpha \lambda_{qr}^s \frac{d\lambda_{qr}^s}{dt})
\]  \tag{21}

The adaptive reference equations are written as follows:

\[
\frac{d\lambda_{dr}^s}{dt} = -\frac{1}{t_r} \lambda_{dr}^s + \tilde{\omega}_r \lambda_{qr}^s + \frac{1}{t_r} i_{ds}^s
\]  \tag{22}

\[
\frac{d\lambda_{qr}^s}{dt} = -\frac{1}{t_r} \lambda_{qr}^s + \tilde{\omega}_r \lambda_{dr}^s + \frac{1}{t_r} i_{qs}^s
\]  \tag{23}

Rotor actual speed is estimated by using the error, which is the difference between adaptive reference and model reference system, as shown in equation 24. The zero error occurs when the references produce same values.

\[
\varepsilon = \tilde{\lambda}_{dr}^s \lambda_{qr}^s - \tilde{\lambda}_{qr}^s \lambda_{dr}^s
\]  \tag{24}

Generally, MRAS can be used if pure integration is possible. But it is not possible on the microcontroller certainly. To overcome this problem, nonzero-flux initial condition and offset in the voltage/current, low pass filter can be used instead of an integral. In this paper, adaptation mechanism consist of PI as a controller, as given in equation 25.

\[
\tilde{\omega}_r = \left(K_p + \frac{K_i}{s}\right) \varepsilon
\]  \tag{25}

V. EXPERIMENTAL RESULTS

In these experiments, open-loop, sliding-mode and MRAS based speed estimation techniques are compared at starting, ramp based acceleration, reverse operation and instant speed changing with no-load. All algorithms run on STM32F407 discovery kit working at 167 Mhz. Also, the compact design IGBT module, named as 7MBP50VDA-120-50, is used for switching components. The calculated data getting from microcontroller are sent to computer by wireless commutation after the operations.

A. Starting Characteristics

The operation is started at zero speed and finished at 314.16 rad/s. Firstly, open-loop estimation method has an initial problem. On the other hand, it has better performance than the others at steady state. However, MRAS technique is more stable at all time (e.g. Fig. 4).
B. Ramp Reference Operation

On ramp operation, speed estimators performance observed during 2 second are compared at synchronous speed. The ramp value reaches the synchronous speed at 1 second. Minor changes are observed on the starting characteristics. First one, an open-loop initial point is changed. Also, sliding-mode has more oscillation with respect to the previous operation. Also, MRAS based estimation has no significant changes (e.g. Fig. 5).

A. Change in Speed (Speed Tracking)

With sliding-mode technique, rotor speed has some ripples like in the previous operations modes. The best algorithm on the operation can be said to be MRAS method (e.g. Fig. 6).

B. Reverse Operating

The experimental operation is carried out at half of the synchronous speed of the induction motor. At 5.5th second, speed is the same, but rotation is reversed. It is shown that open-loop estimators has the best time for reaching to the reference point. For the reverse directed speed and braking mode, all algorithms have nearly almost the same decelerating time. But MRAS has the most change in speed at positive speed side (e.g. Fig. 7).

VI. CONCLUSION

Open-loop estimation method is more stable at the large part of the operations with the exception of starting point problem. On the other hand, sliding-mode method has more ripples than others. The method, MRAS, is minimized ripples at steady-state and its initial condition is the best on all working operations.

VII. APPENDIX

The Motor Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Power</td>
<td>11 kW</td>
</tr>
<tr>
<td>Rated Voltage</td>
<td>380 V</td>
</tr>
<tr>
<td>Rated Frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Rated Speed</td>
<td>1470 rpm</td>
</tr>
<tr>
<td>Stator Resistance</td>
<td>1.1 Ω</td>
</tr>
<tr>
<td>Rotor Resistance</td>
<td>1.6 Ω</td>
</tr>
<tr>
<td>Magnetizing Inductance</td>
<td>0.351 H</td>
</tr>
<tr>
<td>Stator Leakage Inductance</td>
<td>0.3615 H</td>
</tr>
<tr>
<td>Rotor Leakage Inductance</td>
<td>0.3615 H</td>
</tr>
<tr>
<td>Inertia</td>
<td>0.077 kg m²</td>
</tr>
</tbody>
</table>
REFERENCES


Adaptive Controller Design Based On Fractional Order Memristors

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Abstract— After the memristor, which passive electrical component relating electrical charge and magnetic flux linkage and it was known as lost element since 1971, has been found by researchers in Hp Lab, it has been the focus of attention of researchers. For analysis of the memristor, analog circuit model of memristors is generally used. In this paper, using fractional order a memristor model, fractional order adaptive PI controller has been designed. For performance analysis of the controller, it has applied to control of nonlinear system, and compared classical PI controller.

1. Introduction

Memristors are known as the materials representing the link between the charge and flux suggested as the missing element by Chua. It has been known as the missing element since 1971, however it has been found this material's entity at the result of a research in Hp laboratory in 2008 [1-3]. Because of memristor's feature to hold the last resistance value as a passive circuit element (likely to be used as a passive memory element) has increased interest in these materials. Studies on the memristors have risen more and more after 2008. These studies have generally spread into many different scientific fields like; memristor emulator circuits [4-8], production methods [8-14], applications on communication systems [15], nonlinear circuit design [16-18]. In some of these studies, it has been observed that the usage of memristor affects system performance positively. Besides the model of memristor developed in Hp laboratory, the idea of using the emulator circuit in practice is still widespread. One of these studies is the model put through by Muthuswamy [19]. It has been observed that Chua circuit, composed by using this model, demonstrates chaotic behavior.

Memristor are defined as the ratio of the change in raids over the last load changes. It has been known that the change of flux in terms of current is inductance, the change of current in terms of voltage is resistance, and the change of voltage in terms of load is capacitor. According to these definitions, as the element representing to the change rate between flux and load as the fourth relation had not been found, it was called as missing element. After finding this element, studies has determined the relation between load and flux as a function of fractional order, the behavior of this element has begun to be the subject for new researches [20-22].

Modeling of fractional order systems known as the systems having system degree's any real number except whole numbers [20-23] has practices in many fields such as control systems [24-25], effects on chaos behavior [26-27], communication systems [28]. The studies exercised fractional order systems on circuit models have proved that system degree could be changed according to circuit topology made by using passive circuit elements [29]. One of the most common practicing field of fractional order systems is control system. Having wider stability domain at control systems and performing in a good way at controlling nonlinear systems have increased the interest in this type of controllers [30]. The behavior of a controller designed with fractional order memristors which is a fractional order nonlinear element still remains uncertain.

In this study, PI type controller has been designed by using fractional order memristor from model of memristor in literature. The performance of a nonlinear system on control has been measured with this controller designed by using analog circuit designation method. To evaluate controller performance, it has been compared with performance of PI controller occurred with classic memristors. The effect of controller parameters on control system has been investigated.

The study was organized like above. The structure and mathematical model of classic memristors and fractional order memristors have been investigated in II. section. In III. section, the applications of classic memristors and fractional order memristors on control systems has been investigated. In IV. section, simulation results have been given. In conclusion, the results have been investigated.

2. Memristors

2.1. Classic Memristors

Memristors have been found at HP laboratory in 2008 after Chua suggested this as an idea. According to this model, the relation between voltage and current applied to circuit has been given at Equation I. [1-2].
\[
M(q) = \frac{v(t)}{i(t)} = R_{on} \frac{\mu R_{on}}{D^2} q(t) + R_{off} (1 - \frac{\mu R_{on}}{D^2} q(t))
\]

\[
\frac{\mu R_{on}}{D^2} = A
\]

(1)

Here, TiO weight of D memristor is the load mount flowing over q(t) memristor, and R_{on} is defined as on-position resistor of circuit, R_{off} is defined as off-position of circuit. As R_{on} resistor value of memristor model is so bigger than R_{off} resistor value, the statement in Equation 1 would be changed as given in Equation 2[4].

\[
M(q) = \frac{d\phi}{dq} \approx R_{off} (1 - Aq(t))
\]

(2)

The emulator circuits of memristors had been studied before this circuit element was found in Hp lab. With using this mathematical model, the circuit model which was occurred by Muthuswamy has been demonstrated in Figure 1[19].

![Memristor emulator circuit](image)

**Figure 1 Memristor emulator circuit [19]**

### 2.2 Fractional Order Memristors

#### 2.2.1 Fractional Calculus

Fractional order systems are based on fractional calculus. Although fractional order calculus is old mathematical method, researchers are still studying solutions using this method. Fractional order systems have many solution techniques. These techniques are the Grunwald–Letnikov (GL) method (Eq. 3) and the Riemann–Liouville (RL) method (Eq. 4) [20,22]. The GL equation is described as following:

\[
D_t^\alpha f(t) = \lim_{h \to 0} \frac{1}{\Gamma(\alpha)} \int_{t-h}^{t} \frac{(t-\tau)^{\alpha - 1}}{\tau^\alpha} f(\tau) d\tau
\]

(3)

For fractional order systems, another solution technique is Euler method which was given (5), generalized derivative of fractional order systems[20].

\[
D^\alpha f(t) = \frac{\Gamma(n+1)}{\Gamma(n-\alpha+1)} \int_{t}^{f(t)} (t-\tau)^{-(n-\alpha)} d\tau
\]

(4)

For the solution of main fractional order systems, it is a useful method in a lot of studies. Laplace transform method is another very popular solution method in the literature that we used the method in the paper.

Laplace transforms of fractional systems are defined as following:

\[
L \left[ \frac{d^\mu f(t)}{dt^\mu} \right] = s^\mu F(s)
\]

\[
\mu \in \mathbb{R}
\]

There are many approaches to solve s^\mu Laplace operators. Some of these approaches are the Crone, Carlson and Matsuda methods[20,22,29]. The most widely used approximation of s^\mu is Crone. Crone is a French acronym (non-integer order robust control — Commande Robuste d’Ordre Non-Entier) [23]. In the Crone approximation, s^\mu is calculated as;

\[
s^\mu \approx C \prod_{a=1}^{\infty} \frac{s}{\omega_{p,a}^{(2\mu+1)}}
\]

(7)

\[
\omega_{p,a} = \omega_b \left( \frac{\omega_b}{\omega_l} \right)^{\frac{2\mu+1}{2\mu}}
\]

(8)

where C, \omega_b and \omega_l can be chosen as;

\[
0 < \omega_l < \omega_b
\]

\[
C > 0, \mu \in (0,1)
\]

(10)

In fractional order systems, Laplace and Crone approximations are useful methods. Therefore, several research studies use these approximations.

#### 2.2.2 Mathematical Model of Fractional Order Memristors

At previous sections in classic memristors, the change of load according to flux was discussed, in fractional
order memristors this dependence can be defined as fractional order [21].

\[ M^\alpha (t) = \frac{d^\alpha \phi}{dq^\alpha} \] (11)

Fractional order memristor can be defined as mathematical model over classic memristor performed in Hp laboratory as;

\[ M^\alpha (t) = \frac{d^\alpha \phi}{dq^\alpha} \approx R_{off} \left[ 1 - A(D_t^\alpha i(t)) \right] \] (12)

2.2.3. Circuit Model of Fractional Order Memristors

Fractional order memristor can be obtained in the event integrator from the model composed by Muthuswamy is fractional order. Circuit model of this model has been given in Figure 2. When sinusoidal voltage has been applied to this model, the change of current over circuit element has been given in Figure 3. As it can be seen from current and voltage graphic, besides fractional order memristor shows familiar feature like classic memristor on mathematical model, it can be seen exit of circuit model.

3. Application of Fractional Order Memristor to Controllers

3.1. Application of Classic Memristors to PI

In the studies on the applications of classic memristors on PI controllers, it is known that PI controllers with classic memristors perform faster and more powerful. Such a controller model has been demonstrated in Figure 4 [31].

Mathematical model for memristors is given as Equation. 13.

\[ \frac{U_2}{U_1} = \frac{RCs + 1}{MCs} \]

\[ M = R_{off} \left[ 1 - \frac{AC}{1 + RCs} U_2 \right] \] (13)

3.2. Application of Fractional Order Memristors to PI

One of possible application field of memristors is controller system. When using a memristive element at the proportional processing of classic PI circuit, circuit model becomes as shown in Figure 5.

Mathematical model of this circuit model is nonlinear fractional order model.
\[ v_0(t) + \frac{A}{R} v_0(t) D^\alpha v_0(t) \approx \frac{R}{R_{off}} v_i(t) \]  
(14)

Mathematical model occurred from this circuit model (given in figure 5) has been demonstrated in Equation 10.

\[ v_0(t) + \frac{A}{R} v_0(t) D^\alpha v_0(t) \approx \frac{R}{R_{off}} v_i(t) \]  
(15)

4. The Results

In this study, synchronization control of two fractional order Van-der Pol oscillator has been performed for testing performance of control system. Mathematical model of Master and Van der Pol oscillator is like;

**Master**

\[ x^{(1+\lambda)} + \alpha(x^2-1)x^{(\lambda)} + x = 0 \]

**Slave**

\[ x^{(1+\lambda)} + \alpha(x^2-1)x^{(\lambda)} + x + u = 0 \]

\[ 0 < \lambda < 1 \]

\[ \lambda \in R \]  
(16)

Here \( u(t) \) is controller entrance and function produced depending on error with designed controller.

4.1. Simulation Results

Circuit model, used on synchronization of two Van-der Pol chaotic systems with PI controller occurred with fractional order memristor, has been shown in Figure 6. At circuit models; Master chaotic Lorenz oscillator circuit has been shown in Figure 6a, Slave chaotic Van-der Pol circuit has been shown in Figure 6b and fractional order memristor controller has been shown in Figure 6c. According to these parameters, the change of system exit has been given in Figure 7. In this figure, the first graphic (Figure 7a) shows the simulation result obtained from mathematical model of the system. The change obtained from circuit model result has been given in Figure 7b. The similarity of both these graphics can be seen at 2 figures.

5. Discussion and Conclusion

In case of memristor which is very popular element in electronic, can use in control systems, it provide adaptive control performance. In this Study, an effective method to PI
controller based on memristive has been presented and we have generalized the order of the memristor for real number set. It is applied Van-der Pol chaotic synchronization circuit and Simulink model in order to test of controller performance. As the memristors have nonlinear behaviour between current and voltage, the systems based on memristor can have adaptive control performance. The obtained Simulink and circuit simulation results shows that synchronization control of nonlinear Van-der Pol oscillators is performs better results than classical PI controller.

References


Dual-Hop Decode-and-Forward IDMA Networks over Nakagami-\textit{m} Fading Channels

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Abstract—This paper investigates the bit error probability (BEP) of dual-hop interleave-division multiple access (IDMA) systems with decode-and-forward (DF) relaying over Nakagami-\textit{m} fading channels. A closed-form approximate BEP expression for the considered system is derived. In particular, we present a detailed performance comparison for binary phase shift keying (BPSK) modulation. Computer simulations are also presented to confirm the analytical results. Our findings show that the results obtained by the derived BEP expression are sustained through computer simulation results.

Keywords—Dual-hop DF IDMA, Nakagami-\textit{m} fading, bit error probability.

I. INTRODUCTION

Dual-hop communications technique in wireless systems has attracted a considerable research attention [1-6]. Most existing studies about dual-hop transmission systems mainly focus on different performance metric, system model and different fading channel conditions. In [1], an analytical framework for the performance evaluation of dual-hop decode-and-forward (DF) systems operating over $\eta-\mu$ fading channels in the presence of cochannel interference and additive white Gaussian noise (AWGN) is provided. Simple accurate analytical expressions for the outage probability, average bit error probability (ABEP), and average capacity are derived. The outage performance of dual-hop DF cooperative systems is considered over an interference-limited Nakagami-\textit{m} fading environment [2]. In [3], the authors analysed the dual-hop DF relaying systems with multiple interferers over Rayleigh fading channels. They derived the closed-form expressions for the outage probability of their system. In another work in [4], the exact closed-form outage probability expression is presented for an L-relays dual-hop system over Nakagami-\textit{m} channels. They concluded that an optimal number of relays should be used depending on the channels conditions. Lee et al. investigate the symbol-error-rate (SER) performance of DF cooperative communications with multiple dual-hop relays and they considered Nakagami-\textit{m} fading for the source-relay and relay-destination links [5]. However, the analytical result for the SER performance of the considered system has no closed-form expression. In [6], the outage probability derivation of the DF dual-hop system with an interference-limited environment is presented. The performance of two-hop DF relaying protocol under mixed faded channels by evaluating outage probability and average bit-error probability was investigated in [7]. Several authors have studied the performance of different communication systems based on dual-hop relaying transmission [8-12]. The end-to-end error probability performance of a dual-hop orthogonal frequency division multiplexing (OFDM)-based relaying system is examined [8]. The other study in [9], the authors study the performance of a dual-hop multiple-input multiple-output (MIMO) wireless communication system using orthogonal space-time block codes. The considered channel model is correlated Nakagami-\textit{m} fading in their work. Xu et al. investigated the outage probability of a dual-hop DF cognitive relay network over Rayleigh fading channels in the presence of the primary user’s interference. Also, the exact and asymptotic outage probabilities for the considered system were derived in [10]. Most recently, in [11], the performance of direct-sequence code division multiple access (DS-CDMA) based on two-hop amplify-and-forward protocol over Weibull symmetric fading channels as well as Rayleigh/Rician, Rician/Rayleigh asymmetric fading phenomenas based on simulations are analysed. Dual-hop $N$-relay assisted transmission scheme for interleave-division multiple access (IDMA) with DF relaying was proposed in [12] to improve the performance of IDMA systems. The authors in [12] are considered Weibull fading channels, but they presented the error performances of their system by means of the simulations.

The existing works on dual-hop relaying in [1-7] are limited to analysing only dual-hop relaying transmission without combination of different communication protocols. The previous works in [8-12] presented the performance metrics with the help of simulations or considered different fading conditions. Although dual-hop relaying has been studied in different wireless communications systems, it has not yet been investigated in the context of dual-hop DF IDMA systems over Nakagami-\textit{m} channels. In this paper, the dual-hop DF IDMA system over Nakagami-\textit{m} fading channel is provided. The bit error probability (BEP) for dual-hop DF IDMA systems is analysed. In particular, an approximate closed-form expression for BEP of dual-hop DF IDMA is derived by employing Rake detector at the relay and destination node. The analytical results obtained by the derived BEP expression are validated by computer simulations.
II. DUAL-HOP DF IDMA SYSTEM MODEL

As shown in Fig. 1, we consider a dual-hop DF IDMA system where the transmissions of user $k$ are assisted by $N$ relays installed with the DF protocol. Two transmission slots are needed to convey source information. The first transmission slot is to transmit information from the user $k$ to all relays in the system. The received signal $n$th relay node is given by

$$r_{SR}(t) = \sum_{j=0}^{T_s-1} h_{SR}(j) d_k(j) \pi_k^j (t - j T_s - \tau_{SR}) + n_{SR}(t)$$

where $h_{SR}$ is the channel gains for source- $n$th relay, $\tau_{SR}$ is delay for source- $n$th relay link, $d_k$ is the $j$-th transmitted symbol of the user $k$. $J$ is the frame length, $T_s$ is the symbol period, $n_{SR}$ is Additive White Gaussian Noise (AWGN) term. $\pi_k^j$ is the combination of the spreading and interleaving waveform of the user $k$ used by $S$ during the $j$-th symbol period.

In the second transmission slot, the $n$th relay decodes the source information, reencodes and then forwards it to the corresponding destination. The received signal at the destination node is expressed as

$$r_{RD}(t) = \sum_{j=0}^{T_s-1} \sum_{i=1}^{K} h_{RD}(j) \hat{d}_k(j) \pi_k^i (t - j n T_s - D_{k,s} - \tau_{RD}) + n_{RD}(t)$$

where $h_{RD}$ is the channel gain for $n$th relay-destination, $\tau_{RD}$ and $D_{k,s}$ are random delay and the transmission delay during the second time slot for $n$th relay-destination link, respectively. $\hat{d}_k(j)$ is the decoded source signal for user $k$ at $n$th relay node. $n_{RD}$ is AWGN term and $N$ is the number of relays in the system. $\pi_k^i$ is the spreading and interleaving waveform of the user $k$ used by $n$th relay during the $j$-th symbol period. Finally, destination node uses a Rake receiver to estimate the data message from different relays. Then, these soft estimates of the data message are combined by using a maximum ratio combiner (MRC).

Assuming perfect channel estimates, the instantaneous signal-to-noise ratio (SNR) at the Rake receiver output for both $n$th relay and destination in the system is written by [13]

$$\gamma_{SR} = \frac{E_s}{N_0} [h_{SR}]^T g_{SR} h_{SR}$$

$$\gamma_{RD} = \frac{E_s}{N_0} [h_{RD}]^T g_{RD} h_{RD}$$

where $h_{SR}$ and $h_{RD}$ are the channel gains for source-$n$th relay and $n$th relay-destination links, respectively. $E_s$ is the transmitted energy per symbol. $g_{SR}$ and $g_{RD}$ are $(1 \times 1)$ matrix for cross-correlation of delayed waveforms due to the single-path propagation. $[\cdot]^T$ is complex transpose operator.

![Fig. 1 Schematic diagram of a dual-hop DF IDMA system model for user $k$.](image)

III. PERFORMANCE ANALYSIS

We now derive an approximate BEP expression for a dual-hop DF IDMA system model described in Section II. In doing so, we begin with the commonly known BEP formulation for the considered system:

$$P_e = \sum_{\alpha} P_{\alpha} p(\alpha)$$

where $\alpha$ is the set of relays which correctly decoded and $P_{\alpha}$ is the conditional error probability at destination node. $p(\alpha)$ that is the error probability for the indirect transmission and is given by

$$p(\alpha) = \prod_{n=a}^{b} (1 - P_{\alpha,n}) \prod_{j=a}^{b} P_{\alpha,j}$$

where

$$P_{\alpha,n} = \int_{0}^{\infty} A Q(B \gamma) p_{\gamma,n}(\gamma) d\gamma$$

Eq. (7) is the average BEP at $n$th relay. $A$ and $B$ are constants that depend on the modulation type (for example $A = 1$, $B = 2$ for binary phase shift keying (BPSK)) [14]. $Q(x)$ is Gaussian $Q$-function defined by $Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} \exp(-t^2 / 2) dt$. $p_{\gamma,n}(\gamma)$ is the probability density function (PDF) of the total instantaneous SNR at $n$th relay node. $P_{\alpha,n}$ is the same as $P_{\alpha}$ after replacing the subscript $n$ with $j$. In order to find $p_{\gamma,n}(\gamma)$, the moment generating function (MGF) of $\gamma_{SR}$ is given by

$$M_{\gamma,n}(s) = E[\exp(\gamma_{SR})] = \left(1 + s \frac{\gamma_{SR}}{\sigma_{SR}^2}\right)^{-m_{SR}}$$
where \( \overline{\gamma}_{SR} \) is the average SNR and \( \overline{\gamma}_{SR} = \lambda_{SR} \frac{E_s}{N_0} \). \( m_{SR} \) is the Nakagami-\( m \) fading parameter for source-\( n \)-th relay link. \( \lambda_{SR} \) denote eigenvalue of both path delay and the correlation matrix of channel gains related to source-\( n \)-th relay link. Using the fraction decomposition for \( M_{\gamma_{SR}}(s) \), we obtain
\[
M_{\gamma_{SR}}(s) = \omega_{SR} \left( 1 + \frac{s}{\overline{\gamma}_{SR}} \right)^{-m_{SR}} \tag{9}
\]
where \( \omega_{SR} \) is the residue value. By using the inverse Laplace transform of (9), we deduce \( p_{\gamma_{SR}}(\gamma) \) as
\[
p_{\gamma_{SR}}(\gamma) = \omega_{SR} \left( \frac{m_{SR}}{\overline{\gamma}_{SR}} \right)^{m_{SR}} \gamma^{m_{SR}-1} \exp \left( -\frac{\gamma m_{SR}}{\overline{\gamma}_{SR}} \right) \Gamma(m_{SR}) \tag{10}
\]
where \( \Gamma(\cdot) \) is Gamma function. Inserting (10) into (7), we get
\[
P_{e,R} = \int_{0}^{\infty} A Q(B \gamma) \left\{ \omega_{SR} \left( \frac{m_{SR}}{\overline{\gamma}_{SR}} \right)^{m_{SR}} \gamma^{m_{SR}-1} \exp \left( -\frac{\gamma m_{SR}}{\overline{\gamma}_{SR}} \right) \right\} d\gamma \tag{11}
\]
The integral in (11) can be evaluated by using
\[
Q(x) \approx \left[ \frac{1}{12} \exp \left( -\frac{x^2}{2} \right) + \frac{1}{4} \exp \left( -\frac{2x^2}{3} \right) \right] \tag{16}
\]
and using eq. (4). Similar to eq. (16), using the fraction decomposition and inverse Laplace transform evaluation, we can obtain the PDF of total instantaneous SNR. Following to the same steps for (11) and using eqs. (5) and (6), \( P_e \) is derived as
\[
P_e = \sum_{n=1}^{N} \left( \frac{m_{SR}}{\overline{\gamma}_{SR}} \right)^{m_{SR}} \frac{A \omega_{SR}}{\overline{\gamma}_{SR}} \left[ \frac{(Z_1 + \Lambda_2)^{m_{SR}}}{12} \right] \tag{15}
\]
Each integral term in (13) can be evaluated using [17, eq. 3.381.4]. After some mathematical manipulations, an approximate \( P_{e,R} \) expression is derived as
\[
P_{e,R} \approx \frac{A \omega_{SR} \left( \frac{m_{SR}}{\overline{\gamma}_{SR}} \right)^{m_{SR}}}{\overline{\gamma}_{SR} \Gamma(m_{SR})} \left[ \begin{array}{c} \left( -\frac{B}{2} - \frac{m_{SR}}{\overline{\gamma}_{SR}} \right)^{m_{SR}} \\ \frac{4}{12} \end{array} \right] \tag{14}
\]
IV. NUMERICAL EXAMPLES
In this section, the performance of the dual-hop DF IDMA system is evaluated via analytical results and validated through simulations for BPSK modulation. In the considered system, the Nakagami-\( m \) links among the source, relays and destination are independent and identically distributed. Without loss of generality, we assume equal noise powers at all the nodes.
In Fig. 2, the performance of the dual-hop DF IDMA system for $m = 2.5$ and different number of relays is shown. It can be observed that the error performance improves with increasing SNR. Fig. 2 shows, as expected, precise agreement between the results obtained from the theoretical analysis and simulation results at greater than 8 dB.

![Graph showing Bit error probability vs. SNR](image)

Fig. 2 Bit error probability of the dual-hop DF IDMA system versus average SNR for $m = 2.5$ and different number of relays.

The performance of a dual-hop DF IDMA system with $N = 3$ is better than that of a DF IDMA system with $N = 1$. For example, an error probability of $10^{-3}$ happens at SNR $\approx 6$ dB for $N = 3$, while it occurs at SNR $\approx 13.2$ dB for $N = 1$. It can be noticed from the curves in Fig. 2 that dual-hop DF system performances are affected by the number of relays.

V. CONCLUSIONS

New theoretical approximate solution for BEP of a dual-hop DF IDMA network over Nakagami-$m$ fading links have been derived. The exponential-type Gaussian $Q$-function approximation was used to obtain the theoretical results for error probability of the considered system. The effect of increasing the number of relaying nodes in the network were investigated as well as simulation results were used to verify the analytical results obtained by the proposed BEP expression. The results were shown that while the number of relays in the system increases, a notable SNR gain is occurred.

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Performance of Dual-Hop DS-CDMA Systems with AF Relaying over Rician Fading Channels

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Abstract—This paper presents the bit-error rate (BER) performance of direct-sequence code-division multiple access (DS-CDMA) systems with dual-hop amplify-and-forward (AF) transmission over flat Rician fading channels. In the considered system, a source node communicates with a destination node via N relay nodes. BER results are obtained via extensive computer simulations by varying the number of relay nodes and the value of Rician K factor. It is shown that the performance of a DS-CDMA system is improved by using multiple AF relays.

Keywords—DS-CDMA, amplify-and-forward, Rician distribution, BER, Dual-hop.

I. INTRODUCTION

Recently, dual-hop relaying techniques known as amplify-and-forward (AF) and decode-and-forward (DF) are considered promising solutions due to their possible application in the wireless and mobile communication systems. AF relaying in which the relay (R) amplifies the source (S) information and then sends it to destination (D) is an important method to implement relay systems [1]. Dual-hop relaying techniques provide connectivity when direct transmission from S to D node is not practical because of deep fading conditions [2]. Dual-hop AF relaying can be applied to spread spectrum communication systems such as direct-sequence code-division multiple access (DS-CDMA) systems. Several studies have focused on performance of dual-hop relaying techniques without DS-CDMA systems [3-10]. In [3] and [4], the bit-error probability and outage probability of dual-hop AF relaying protocols are presented when the channels are subject to mixed fading cases such as Rayleigh/Rician and Rician/Rayleigh. The performance of dual-hop AF transmission without DS-CDMA principle is investigated over Nakagami-m/Rician fading channels [5]. Spalevic et al. [6], investigated the performance of a two-hop AF relaying system under asymmetric fading environments. The authors in [7] presented the performance of dual-hop AF relaying systems over Rayleigh/Rician and Rician/Rayleigh fading channels. In [8], the authors proposed exact expressions for probability density function (PDF) and cumulative distribution function (CDF) of dual-hop AF relaying systems over Nakagami-m and Rician fading channels. The performance of two-hop relaying systems was investigated over Rayleigh/Gamma and Rayleigh/Weibull fading conditions in [9] and [10]. Different from [3]-[10], in this work, dual-hop DS-CDMA systems with AF transmission method is investigated over Rician fading channels. In the literature, there are only a few studies dealing with the performance of dual-hop AF relaying based DS-CDMA systems [11-13]. The bit-error rate of a dual-hop DS-CDMA systems with AF technique is investigated over different fading channels by presenting only computer simulations [11]. In another work, the authors analyzed the performance of DS-CDMA system with relaying in the presence of multi-user transmitter pre-processing based on channel impulse responses in [12]. Zappone et al. [13] considered the resource allocation problem in a relaying based DS-CDMA wireless communication system.

In this study, BER performance of N relay assisted dual-hop AF DS-CDMA system is investigated over Rician fading channels. It is considered that the direct transmission between S-D nodes is not possible due to deep fading conditions. In order to maintain the transmission in a conventional DS-CDMA system, N relay assisted dual-hop relaying is adopted. S-R_n and R_n-D channels are subject to Rician fading which provides line-of-sight (LOS) characteristics of a wireless channel. It is shown that BER performance of a conventional DS-CDMA system is improved with the help of dual-hop AF transmission. In addition, increasing the number of R nodes (N) and the value of Rician K factor brings considerable amount of BER improvement.

II. SYSTEM AND CHANNEL MODELS

In Fig. 1, a dual-hop relaying model with N relay nodes is illustrated.

![Illustration of N relay assisted dual-hop relaying system](image_url)

In the considered system, half duplex transmission is considered. The transmission occurs in two transmission phases. Each user is separately considered as an information while the other users are assumed as interference due to the
DS-CDMA principle [14]. In Fig. 2, the structure of $S$ node which consists of $L$ users is shown.

![Fig. 2 Structure of $S$ node with $L$ users](image)

The information of each user, $d_l(t)$, is modulated and spreaded by employing the unique spreading code, $c_l(t)$, for each user. After that, the information of $L$ users is summed and $r_{sr}(t)$ is transmitted to the $R$ nodes. In the first transmission phase, the received DS-CDMA signal at $R_n$ node can be expressed by

$$r_{sr}(t) = \sum_{i=0}^{L-1} \sum_{l=1}^{N} d_i(t) C_t (t - \tau_l - iT_l) h_{sr}(i) + n_{sr}(t)$$  \hspace{1cm} (1)

where $L$ is the number of users, $f$ denotes the frame length, $d_i(t)$ and $C_t$ are the $i$th symbol and the spreading code for the $i$th user, respectively. $T_l$ is the bit period and $\tau_l$ represents transmission delay of the $l$th user. $n_{sr}(t)$ is the additive white Gaussian noises (AWGN) and $h_{sr}$ is the Rician fading coefficient for the $S$-$R_n$ path. The PDF of the instantaneous SNR for $h_{sr}$ can be given according to Rician distribution as

$$f_{\alpha}(\alpha) = \frac{2e^{-K(K+1)}}{\Omega \sqrt{\pi}} \left( \frac{\sqrt{K(K+1)}}{\Omega} \right)^{-\frac{1}{2}} I_0\left(2\alpha \sqrt{\frac{K(K+1)}{\Omega}}\right)$$  \hspace{1cm} (2)

where $\alpha \geq 0$, $K$ is the Rician parameter and $I_0(\cdot)$ is the zeroth order modified Bessel function of the first kind [15]. Then, $R$ nodes amplify the received source information by employing the amplification process as follows

$$\beta = \sqrt{E_s / \left( (E_s | h_{sr} |^2) + N_0 \right)}$$  \hspace{1cm} (3)

$R$ nodes transmits the amplified source information to the $D$ node. In Fig. 3, the structure of $D$ node which consists of $L$ users is depicted.

![Fig. 3 Structure of $D$ node with $L$ users](image)

At $D$ node, the received signal from $R$ nodes, $r_{rd}(t)$ is despreaded by using the unique spreading code of each user's to separate the each user's information. Then, the each user's information is demodulated and decision process is employed to estimate the $l$th user information, $\tilde{d}_l$. In the second transmission phase, the received signal at $D$ node is written as,

$$r_{rd}(t) = \sum_{i=0}^{L-1} \sum_{l=1}^{N} r_{rd}(t - D_l - \tau_l - iT_l) h_{rd}(i) + n_{rd}(t)$$  \hspace{1cm} (4)

where $D_l$ is the time delay, $\tau_l$ is the transmission delay of $R_n$ and $n_{rd}(t)$ is AWGN of the $R_n$-$D$ link. $h_{rd}$ is the Rician channel coefficient of $R_n$-$D$ link and the PDF of the instantaneous SNR for $h_{rd}$ is subject to Rician distribution given by

$$f_x(x) = \frac{2e^{-K(K+1)\chi}}{\Omega \sqrt{\pi}} \left( \frac{\sqrt{K(K+1)}}{\Omega} \right)^{-\frac{1}{2}} I_0\left(2\chi \sqrt{\frac{K(K+1)}{\Omega}}\right)$$  \hspace{1cm} (5)

where $\chi \geq 0$. At $D$ node, maximum ratio combining (MRC) is used to combine received signal from each relays [16]

$$r_{MRC}(t) = \sum_{n=1}^{N} w_n r_{rd}(t)$$  \hspace{1cm} (6)
where $N$ is the number of relays, $w_n$ is the MRC coefficient of the received signal from the $R_n$ node and

$$w_n = \sqrt{E_h \sigma_{sr,d}^2 / \sigma_{sr,d}^2}.$$ 

$h_{sr,d}$ is the conjugate of $h_{sr,d}$ and $\sigma_{sr,d}^2$ is the noise variance of the $S-R_s-D$ link.

### III. SIMULATION RESULTS

This section presents the simulation results for BER performance of dual-hop DS-CDMA systems with AF relaying over Rician fading channels. Number of simultaneous users and spreading length are set to 4 and 32, respectively. Results are plotted versus SNR by assuming binary phase shift keying (BPSK) modulation.

In Fig. 4, BER performance results are illustrated. The simulation results are obtained for different number of relays and different values of Rician $K$ parameter. As can be seen from Fig. 4, increasing the number of relays in the system improves the BER performance of the considered system model.

![Fig. 4 BER performance of dual-hop DS-CDMA systems with AF relaying over Rician fading channels.](image)

For example, the worst performance is obtained when one relay is used with $K = 5$ and the best performance is obtained with $N = 3$, $K = 10$. From Fig. 4, it is evident that the value of $K$ parameter is the major parameter for the performance improvement in the considered system model. As an example, when $N = 3$, $K = 5$ and $N = 3$, $K = 10$, BER results are equal to $\approx 2.8 \times 10^{-3}$ and $\approx 3 \times 10^{-6}$ at 15 dB. Increasing the value of $K$ parameter from 5 to 10 brings considerable BER improvement in this example. In the contrary, using more relays does not bring same improvement for the considered system. This shows that better channel conditions are more important than increasing number of relays in the considered system model.

### IV. CONCLUSIONS

In this study, we simulate BER performance of DS-CDMA systems with dual-hop AF transmission over Rician fading channels. The results are obtained for different number of relays and different $K$ parameter values. It is shown that BER performance of dual-hop DS-CDMA systems is improved with the use of multiple relays and increasing the value of $K$ parameter. From the results, it is obvious that the value of Rician $K$ parameter is more important than the number of relays for the performance improvement in the system.

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Comparison of PWM and PCM Based Digital-Analog Converter Structures

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Abstract—In this work performance limitations of various pulse-width modulation based analog digital converter is analyzed. Then, pulse-count modulation based digital-analog converter is explored. The structures are implemented on Altera™ Stratix III FPGA. A sawtooth test signal is generated to analyze the performance of the DAC structures. Maximum effective resolution is calculated depending on the architecture selected. The paper is especially useful for the practicing engineers who deal with embedded system design and develop pulse-width modulation and pulse count modulation based digital-analog converters on microcontrollers and FPGAs systems.

Keywords—Pulse width modulation (PWM); pulse count modulation (PCM); digital-analog conversion; low pass filter; embedded systems.

I. INTRODUCTION

Pulse width modulation digital-analog conversion is a popular data conversion technique for embedded systems. The advantage of the system is that, the system only requires pulse-width modulator inside the controller and an external RC filtering is required to acquire desired analog signal at the output [1]. Since most of the microcontrollers include pulse-width modulators inside, only an RC filter is required to achieve desired analog signal. The implementation is popular for its low cost and easy configuration [2-5]. The resolution of the PWM DAC is limited by counter range of the PWM generator and switching noise after the filter. As a result, the resolution of the PWM DACs is not adequate for many of the embedded system requirements whenever high resolution is needed.

In [5] an alternative implementation for the PWM DAC, pulse-count modulation (PCM) is defined. The PCM method increases performance; however, the implementation is not possible using internal PWM modules of the microcontrollers. Delta-sigma PWM DACs are provides high resolution [6-8]; however, the implementation of delta-sigma conversion is not possible by using basic PWM modules of general-purpose microcontrollers, rather, it requires digital and analog full custom design blocks which is not suitable for low-cost general-purpose design.

In this work, PWM and PCM DAC structures are implemented using an FPGA board and effective resolution of the DAC structures are analyzed depending on the switching noise at the outputs of the structures.

II. PWM AND PCM DIGITAL-ANALOG CONVERTER

General PWM digital-analog converter (PWM DAC) structure is shown in Fig 1. Here, fsys is the clock frequency of the general system. Duty cycle of the PWM modulator is the input of the system, which is entered as digital value, and analog value at the output is proportional to the duty cycle at the system. PWM modulation frequency must be filtered out to have the desired analog value at the output [2-5]. By employing a simple RC low-pass filter at the output of the PWM modulator, desired analog is output is achieved. A second order RC filter stage provides better implementation of the PWM DAC [5, 9]. Although it is possible to use higher order filters they are not preferred due to increased design cost. Generally, second order filter is sufficient to obtain the desired output [9].

The duty cycle of a pulse width modulator contains the desired analog signal data. The output of the DAC can swing between GND and VMAX. The maximum output voltage at the output node and least significant bit (LSB) amplitude is given as:

\[ V_{\text{MAX}} = V_{\text{DD}} \left(1 - \frac{1}{2^m}\right), \quad (1.a) \]
\[ V_{\text{LSB}} = V_{\text{DD}} \frac{1}{2^m} , \quad (1.b) \]

where \( m \) is the resolution of the \( m \)-bit DAC, i.e., \( m \) is the bit size of the DAC digital input; \( V_{\text{DD}} \) is the supply voltage of the digital system. The normalized value of the analog signal \( s(t) \) can be represented as duty cycle of the PWM:

\[ s(t) = \text{Duty}(t) = \frac{\text{Digital input}}{2^m} \quad (2) \]

Fig. 1. Pulse Width Modulator Structure
The PWM output is composed of two signals, i.e., the desired analog output and pulse-width modulator frequency. Since the analog signal band-width is much smaller than the modulator frequency, the analog signal component of the PWM DAC, i.e. $Duty(t)$ signal is quasi-stationary. Hence, the quasi-stationary part of the signal contains the analog output data. Therefore, the modulator frequency must be filtered out. Fig. 2(a) shows circuit equivalent of PWM DAC. Fig. 2(b) shows the PWM signal in frequency domains, and, Fig. 2(c) shows the time domain switching characteristics. The modulator signal is filtered out using a first order RC filter to have the desired analog output in Fig 2(a). As an example, if the desired analog signal is 0.3V, then the duty cycle of the modulator has to be 30%, if 0.5V analog signal is required, then the duty cycle has to be 50%. The values are normalized to the supply voltage of 1V. The transfer function of simple RC filter at the output of PWM DAC as shown in Fig. 2(a) is:

$$V_{\text{out}}(j\omega) = \frac{1}{1 + j\omega RC}$$  \hspace{1cm} (3)

The cutoff frequency for the desired analog signal can be calculated as:

$$f_{\text{cutoff}} = \frac{1}{\tau} \left( \text{rad/} \text{s} \right)$$ \hspace{1cm} (4)

In Fig. 3, analog outputs are generated using various modulation frequencies. The analog signal is generated by sweeping the duty cycle from %0, %10, ... %90 at each millisecond. Here, supply voltage is selected to be 3.3V. In each of the step outputs, the analog signal band-width is selected to be 20 kHz, and, using (4), $R$ and $C$ values are selected to be 0.8 nF and 10 k\Omega. As can be seen from Fig. 3, removal of modulator noise from the analog signal is very critical to reach a desired output resolution level, if modulation frequency is increased, then output noise level is less at the output. On the other hand, if PWM modulator frequency is increased, then PWM resolution decreases since,

$$f_{\text{PWM, MAX}} = \frac{f_{\text{sys}}}{2^m},$$  \hspace{1cm} (5)

where $m$ is the resolution of the PWM modulator.

The effective resolution of the PWM DAC depends on the pulse-width modulator resolution, desired output frequency band ($f_{\text{cutoff}}$), and the filter performance for the pulse-width modulator frequency suppression. The remaining pulse-width modulator frequency component appears as noise at the output and limits the resolution of the DAC. Even if $m$-bit counter is utilized for the PWM module as shown in Fig. 1, it does not guarantee $m$-bit resolution. The reason is that, if PWM DAC output noise is higher than the $V_{\text{LSB}}$ as given in (1.b), then the effective resolution will be less than $m$-bits.

For most of the applications, a first order RC filter stage is not sufficient for the removal of the PWM noise. In general, second order filter is employed to reach higher resolution levels. Here, in order to reach for the desired resolution requirements an empirical cutoff frequency calculation for a second order RC filter is given. Different types of low-pass
filter structures is also suitable for filtering the switching noise. However, second order RC filter is the simplest topology.

A possible implementation of a second order RC filter is shown in Fig. 4(a). Here, in order to reduce the loading effect, the resistor in the second stage is selected as 2R. Regarding to this, the second stage capacitor value is selected to be C/2. The filter transfer function of the circuit in Fig. 4(a) is:

\[ \frac{V_{out}(s)}{V_{PWM}(s)} = \frac{1}{(RC)^2 s^2 + \frac{5}{2} RC s + 1} \]  

The frequency response of the second order RC circuit in Fig. 4(a) for component values of \( R = 5k \) and \( C = 1nF \) is shown in Fig. 4(b). Here, frequency is 30 kHz. Using the configuration in Fig. 4(a) cutoff frequency can be extracted using SPICE simulations as:

\[ f_{cutoff} \approx \frac{0.1575}{RC} \]  

The calculation is based on the assumption that second order filter asymptotically -40dB/decade amplitude decrease at the output which is represented as in Fig 4.b. The line cut at 0dB point gives empirical equation (7) whenever component values are selected as shown in Fig. 4.a. The calculation eases filter design process.

The second order RC filter shown in Fig. 4(a) has R and 2R resistor values and C and C/2 capacitance values, which provides easy implementation. In addition, the cut-off frequency in (7) provides a fast calculation method without complex filter calculations.

As mentioned, PWM DAC output is severely affected by the switching noise of the pulse-width modulator. As a result, effective resolution of PWM DAC is quite limited. To overcome this limitation, a small modification over the PWM structure can be made to have pulse-count modulation scheme. The pulse count modulation (PCM) scheme is shown in Fig. 5. In this structure, only comparison bits are crossed from MSB to LSB. Equivalent duty cycle is the same as PWM DAC. However, PCM switching frequencies are much higher than PWM DAC. So that, much better effective resolution can be handled. The hardware modification is very easy whenever FPGA implementation or VLSI implementation is available. However, the case is more complicated whenever microcontroller implementation is considered.

PWM and PCM duty cycle scheme for 4-bit modulator is shown in Fig. 6. As the total duty cycle is same over whole period, analog signal output is same for both of the structures. Moreover, switching noise after the RC filter is much less whenever PCM is implemented. PCM switching harmonics are shown in Fig. 7. The switching frequencies of both PWM and
PWM and PCM DACs can be compared. It is obvious that, higher frequency components can be filtered out much easier in PCM since switching harmonics are at much higher frequency points whenever compared to the PWM frequency plot which is shown in Fig. 2.b. Since the harmonics of the PCM modulator resides at much higher frequencies compared to PWM structure, filtering out the switching noise from the desired signal is much effective. As a result, much better effective DAC resolution is possible.

III. EXPERIMENTS AND DISCUSSIONS

To experiment the PWM and PCM DAC, both of the structures are constructed using an FPGA board with Altera’s CycloneIII FPGA. The modulator output is filtered out using second order RC filter as shown in Fig. 4(a). The cutoff frequency of the filter is calculated using (7) as 30 kHz, where $R_1 = 5k$, $R_2 =10k$, $C_1=1nF$ and $C_3 = 0.5nF$. The system frequency $f_{sys}$ is 50 MHz in the system setup.

To compare same structures, a test pattern of sawtooth wave is digitally generated using PWM and PCM DACs with 9-bit PWM and PCM modulators, i.e. $m$ is selected to be 9. The signal outputs of the two of the DAC structures are shown in Fig. 8.

It is obvious that PCM DAC switching noise after the filter gives much better results compared to PWM DAC output. PCM DAC effective resolution is approximately 9-bits. PWM effective resolution is much less, even same size PWM and PCM modulators are implemented. However, PWM effective resolution can also be improved to have better results. To increase effective resolution, $m$ is modified to 7. After that $f_{PWM}$ as given in (5) is increased, then, switching noise is decreased. As a result, 6 to 7 bits of resolution is also achieved using PWM DAC as well. PCM DAC provides 2 to 3 bits of more effective resolution in the provided test setup. The effective resolution is calculated as maximum switching noise measured at the output of the DAC is less than least significant bit amplitude of the DAC.

PCM DAC implementation can also be possible for microcontroller implementations, whenever SPT port is used as PCM modulator source and periodically SPI port is driven by PCM data by reversing the data output as given in the scheme as shown in Fig. 5, which is planned to be next implementation to test the microcontroller performance of PCM DAC structures as well.

IV. CONCLUSIONS

PWM and PCM DACs are constructed using an FPGA development board. Two of the DAC structures requires same hardware resources. However, PCM DAC provided 9-bit effective resolution whereas PWM exhibited up-to 7-bits of resolution due to the fact that PCM switching noise can be more effectively suppressed. PCM DAC can be an alternative solution for FPGA and VLSI implementations whenever a simple and efficient DAC structure with moderate analog frequency band is required.

REFERENCES

A Comparison of Different Patch Shapes Effects on Bandwidth

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Abstract—In this study, a new microstrip patch shape, called Seljuk star, is proposed. The performance of the designed antenna is compared with the performance of square and circular microstrip antennas, which are two other popular patch shapes in literature. The design of the antenna is performed in HFSS. Each individual antenna is intended to be working at a single frequency, but during the simulations multiple resonances are obtained for most of the designs. Therefore, the bandwidth comparisons are done for each time one by one. In comparison to the circular patch shape with the same surface area, bandwidth is improved 10.57 times. The shift between the theoretical calculations and simulations is % 1.38. Again, this is the smallest shifting between all results. Based on this, it is observed that Seljuk star shape microstrip patch antenna has a better performance than circular and square shape microstrip antennas which have the same dimensions or same surface areas with it. The new, proposed Seljuk star patch shape is believed to have a high potential to be used in future research.

Keywords—Seljuk star, microstrip antenna, HFSS, bandwidth enhancement

I. INTRODUCTION

Microstrip antennas are one of the most preferred types of antennas because of their small sizes, low power consumption and consumption for mobile applications today. However, the narrow bandwidth of the microstrip antennas is a major disadvantage. In order to overcome this negative side, many studies have been performed on bandwidth enhancement methods [1-3].

One of the bandwidth enhancement methods that is very common in literature is choosing the optimal patch geometry. Thus, resonant frequency and bandwidth values can be chosen for the structure while maintaining a suitable application for the antenna geometry. In addition, the polarization and radiation characteristics can be adjusted by changing the shape of the patch. [1-3,6-8]

In this study, Seljuk star microstrip patch antenna, a new patch shape in literature, is designed with using the traditional square and circular microstrip antennas and their performances are compared. During designs, a two-phase study was performed. In the first phase, patch dimensions were taken equal to each other for all three patch geometries. In the second phase, the dimensions were chosen as surface areas of the patches would be equal. Except patch dimension, all other antenna parameters didn’t change for aiming to present the effects of the patch shape on antenna performance. Study is described in detail below [2,4].

II. ANTENNA DESIGN

Seljuk star is a special geometric shape which can be easily obtained by placing two equivalent squares with a 45° degree relative to one another can be come across through the whole Islamic geography. The reasons of choosing this shape for antenna design are easy calculation of shape dimensions as geometrically and utilizing the circular antenna expressions in literature. Seljuk star microstrip patch antenna (SSMSA) has advantages in many ways according to other patch shapes and gives opportunities to save area, so the new antenna design can be used in more today’s smaller mobile devices. Also, by adding other bandwidth enhancement methods can be applied to this patch shape it can be achieved successfull antenna performances. [2,4,9].

In Figure 1, SSMSA designed on a square substrate is seen. Rogers Duroid 6010 is prefered as substrate material. It has a dielectric constant of 10.2 and a thickness of 3.175 mm.

Coaxial feedlines were used in all designs. The feed point of the antennas were determined by trial and error in simulation.
media. HFSS is used for simulations [5]. Antenna designs can be seen in Table 1.

![Seljuk Star Microstrip Patch Antenna Design](image)

**Figure 1: Seljuk Star Microstrip Patch Antenna Design**

<table>
<thead>
<tr>
<th>L (mm)</th>
<th>L_{gnd} (mm)</th>
<th>h (mm)</th>
<th>(\varepsilon_r)</th>
<th>x_f (mm)</th>
<th>(f_{r_{Teo}}) (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>47.46</td>
<td>127</td>
<td>3.175</td>
<td>10.2</td>
<td>36</td>
<td>5800</td>
</tr>
</tbody>
</table>

Where:

- **L**: The edge length of the square/ the distance between two corners of Seljuk star
- **L_{gnd}**: The edge length of the ground plane
- **h**: Substrate thickness
- **\(\varepsilon_r\)**: Dielectric constant of the substrate
- **x_f**: Feed point
- **\(f_{r_{Teo}}\)**: The theoretical resonant frequency

In Figure 2, the differences of dimension equality and area equality designs for all three patch shapes are shown.

At first phase, a Seljuk star shape microstrip antenna is designed by choosing the ground plane parameters and resonant frequency as 5800 MHz which are suitable for the available material. Simulations were completed for both dimension equality and area equality designs. After SSMSA was designed, the patch shape was changed into square and circular, respectively. All other antenna parameters were kept constant. They were simulated using HFSS and their performances were compared.

**III. RESULTS**

Simulation results are given in Table 2. From these results, it is obtained that with all patch designs, more than one resonant frequencies are occurred and the largest bandwidth is achieved with SSMSA design. This value of \(1.48\) is not enough for ISM 5800 MHz needs which is \(2.5\), but it is quite larger than the other design bandwidths. From simulation results, it is seen that a bandwidth is obtained which is 10.57 times larger than the other patch shapes. That is the result of Seljuk star design equal area with the circular patch. For the same design, there is only a frequency shift as \(1.38\) between the simulation and the theoretical frequencies. Again, this is the smallest shifting between all results. Based on this, it is observed that Seljuk star shape microstrip patch antenna has a better performance than circular and square shape microstrip antennas which are the same dimensions or same surface areas with it. So, as a new patch shape, Seljuk star will easily find application and study areas in literature.

![Antenna Designs](image)

**Figure 2: Antenna Designs a) equal dimension b) equal area**

<table>
<thead>
<tr>
<th>Patch Shape</th>
<th>(f_{r_{Teo}}) (MHz)</th>
<th>(f_{r_{Sim}}) (MHz)</th>
<th>BW_{Sim} (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seljuk Star</td>
<td>5800</td>
<td>5560</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>5800</td>
<td>5880</td>
<td>1.48</td>
</tr>
<tr>
<td>Square</td>
<td>5800</td>
<td>5550</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>5800</td>
<td>5930</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>5800</td>
<td>5980</td>
<td>0.17</td>
</tr>
<tr>
<td>Circle</td>
<td>5800</td>
<td>5570</td>
<td>0.16</td>
</tr>
<tr>
<td></td>
<td>5800</td>
<td>5910</td>
<td>0.24</td>
</tr>
<tr>
<td>Square area</td>
<td>5800</td>
<td>5550</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>5800</td>
<td>5930</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>5800</td>
<td>5980</td>
<td>0.17</td>
</tr>
<tr>
<td>Circle area</td>
<td>5800</td>
<td>5880</td>
<td>0.14</td>
</tr>
</tbody>
</table>
IV. CONCLUSIONS

A Seljuk star shape microstrip patch antenna is designed then its performance is compared with circular and square shape microstrip antennas that are the popular patch shapes in literature. There are two phases for the designs: First, the patch dimensions of circular and square are taken as the same with Seljuk star. Then the patch surface areas of antennas are fixed to the area of Seljuk star antenna and new patch dimensions are calculated for the new designs. Antenna performances are compared in terms of bandwidth.

As can be seen from simulation results, SSMSA design has superior performance compared to other patch shapes. Also the the target resonant frequency has obtained with a reasonable shifting. However the % 2.5 bandwidth criteria nessecary for WiFi applications could not be matched with % 1.48 bandwidth result. Nevertheless, it’s possible to improve the bandwidth futher by applying the bandwidth enhancement methods.

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Effect of junction recombination velocity of electrical parameters of a vertical parallel silicon solar cell under frequency modulation

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Abstract—This study investigates a theoretical study based on the determination of electrical parameters in solar cell junction vertical parallel silicon under polychromatic illumination and frequency modulation. From the excess minority carrier’s density in the solar cell, the photocurrent density and the photovoltage are derived. The route of the current vs. voltage density (I = f (V)) that materializes the behavior of the generator; we have a model on the shunt resistor and the series resistor. From their expressions, we study their pace according to Bode and Nyquist then extend the study to other electrical parameter. The Bode diagrams of the diffusion capacitance are shown for different junction recombination velocity

Keywords: Photovoltaic, junction recombination velocity, Nyquist and Bode diagramme, series resistance and shunt resistance, capacitance.

I. INTRODUCTION

In order to improve the efficiency of solar cells, various methods for determining electrical [2] and electronic [1] parameters of a silicon solar cell were studied on regime and different illumination modes. These investigations have identified some adverse effects to the performance of the solar cell. Include among others : the drastic effect of the series resistance and shunt conductance on the performance of the solar cell [3]; the effect of incidence angle on the electrical parameters of a solar cell to vertical parallel junction [4,5]; the effect of the size of the grain boundaries on a solar cell under illumination multispectral [6] etc.

In this present article, we will determine the expression of the density of minority carriers, the photocurrent density and photovoltage. Study of the characteristic photocurrent - photovoltage (I- V) where each point of the shape defines a specific operating state of the solar cell, the electrical parameters (series and shunt resistance) will be deducted.

From Bode and Nyquist diagrams enlargement of the capacitance study, the predominant effects will be listed and analysis will be on the impact of the frequency of these parameters and the effect on junction recombination velocity.

II. MATHEMATICAL DEVELOPMENT

Figure 1 represents parallel vertical junction silicon solar cell under various junction recombination velocity in the base. This study is based on a bifacial silicon solar cell with an n+-p-p+ [7,8] structure (figure 1). Given 20 that the base has a greater contribution to photocurrent, the following analyses have been conducted only in this region.

Under the effect of the exciting light, there is a generation of minority carriers (electrons) and majority (holes) called electron-hole pairs in the database. The contribution of the transmitter (the thickness is 1 µm) is neglected at the expense of the base [9] which is the predominant area of absorption phenomena, generation, recombination and diffusion of the charge carriers. From these phenomena it governs the continuity equation of minority charge carriers in the following basis:

$$D(\omega) \frac{\partial^2 \delta(x,t)}{\partial x^2} - \frac{\delta(x,t)}{\tau} + G(z,t) = \frac{\partial \delta(x,t)}{\partial t} \quad (1)$$

Where $\delta(x,t)$ [10] and $G(z, t)$ [11] respectively represent the density and the generation rate of minority charge carriers as a function of depth $z$ and time $t$. Their expressions are given respectively by the relations (2) and (3):

$$\delta(x,t) = \delta(x) \times \exp( j \omega t) \quad (2)$$

$$G(z,t) = G(z) \times \exp(j \omega t) \quad (3)$$
As the illumination is polychromatic, \( G(z) \) [12] is written as follows:

\[
G(z) = \sum_{i=1}^{i} a_i \times \exp(-b_i z) \tag{4}
\]

With \( a_i \) and \( b_i \) tabulated coefficients of solar radiation defined under AM (air mass) (solar spectrum) = 1.5 [12].

\( \omega, \tau \) and \( D(\omega) \) [13] respectively called by the terms modulation frequency, average duration (in \( \mu s \)) and complex diffusion coefficient of minority charge carriers in the base. This is expressed as follows:

\[
D(\omega) = \frac{D(1 + \omega^2 \tau^2)}{(1 + \omega^2 \tau^2)^2} \left[ 1 - j\omega \tau \right] \tag{5}
\]

Substituting equations (2), (3) and (4) in equation (1) we obtain equation (6):

\[
\frac{\partial^2 \delta(x)}{\partial x^2} - \delta(x) + G(z) = 0 \tag{6}
\]

With \( L(\omega) \) the complex diffusion length expressed as follows:

\[
L(\omega) = L \times \sqrt{\frac{1 - j\omega \tau}{1 + \omega^2 \tau^2}} \tag{7}
\]

From the equation (6) we obtain the solution (8).

\[
\delta(x) = A \sinh \left( \frac{x}{L(\omega)} \right) + B \cosh \left( \frac{x}{L(\omega)} \right) + \sum_{i=1}^{i} \frac{a_i}{1 + \omega^2 (b_i \tau)^2} \exp(-b_i z) \tag{8}
\]

Coefficients \( A \) and \( B \) are determined through the following boundary conditions [14, 15]:

- at emitter-base junction \( (x = 0) \):
  \[
  D(\omega) \frac{\partial \delta(x)}{\partial x} \bigg|_{x=0} = S_f \delta(x) \bigg|_{x=0} \tag{9}
  \]

\( S_f \) is the excess minority carrier’s junction recombination velocity. It has two terms:

- \( S_f = S_{f_0} + S_{f_b} \)

\( S_{f_0} \) or intrinsic junction recombination velocity induced by the shunt resistor and \( S_{f_b} \) the flow of current required by a load imposing the operating point of the solar cell [16, 17].

- at the middle of the base \( (x = H/2) \):
  \[
  \frac{\partial \delta(x)}{\partial x} \bigg|_{x=H/2} = 0 \bigg|_{x=H/2} \tag{10}
  \]

with \( H \): the total thickness of the base (0.03\( \mu m \)).

III. RESULTS AND DISCUSSION

A. PHOTOCURRENT DENSITY

The photocurrent density is obtained by the minority carrier gradient at the junction \( (x=0) \) and is given by the Eq. (11).

\[
J_{ph} = 2 \cdot q \cdot D(\omega) \cdot \left. \frac{\partial \delta(x, \omega, z, \lambda)}{\partial x} \right|_{x=0} \tag{11}
\]

\( q \) is the charge minority carriers. For different excitation frequencies, we represent in the figure 2 the photocurrent density as a function of the junction recombination velocity. Based on the excess minority carrier density, we can determine the photo voltage across the junction.

![Figure 2: Photocurrent density versus the junction recombination velocity for different values of the logarithm of frequency.](image)

The analysis of the figure shows that the photocurrent density increases with increasing the junction recombination velocity for different frequencies. However the amplitude is larger for low excitation frequencies (static regime). In high frequencies the solar cell does not have time to relax and hence the decrease of the amplitude of the photocurrent [18].

For the low values of \( S_f (S_f = 2.10^6 \text{cm.s}^{-1}) \), the photocurrent density is very low because few minority carriers across the junction: the solar cell works in the vicinity of the open circuit while for large values of \( S_f (S_f = 4.10^6 \text{cm.s}^{-1}) \), a large number of minority carriers across the junction where the maximum current. This is the neighborhood of the short circuit.

B. PHOTOVOLTAGE

According to the Boltzmann’s relation, the photovoltage is obtained by the expression. (11) [19, 20]:

\[
V_{ph} = \frac{K \cdot T}{q} \ln \left[ 1 + \frac{N b}{n^2} \delta(x) \bigg|_{x=0} \right] \tag{11}
\]

with

\[
V_T = \frac{K \cdot T}{q}
\]
where q is the electronic charge, $V_T$ the thermal voltage, Nb (10^23cm^-3) the base doping density and $n_0$ is the intrinsic concentration of minority carriers (1.55*10^10cm^-3),
K: the Boltzmann constant (1.38*10^-23 m^2kg/s^2K^-1).
T: the absolute temperature

**C. I-V CHARACTERISTIC**

We present in fig. 3 the profile of the photocurrent density versus the module of the photovoltage for various angular frequency.

![Image](https://via.placeholder.com/150)

**Figure 3** Characteristic current-voltage various incidence angles.

$\omega = 10^2$ rad/s, $H = 0.03$cm, $L_o = 0.02$cm, $D_o = 26$cm²/s, $S_f = 2.10^3$ cm²/s

a) Ideal current generator $J = J_{sc}$ (short circuit current). b) Ideal voltage generator $V = V_{oc}$ (open circuit voltage). c) Ideal photovoltaic cell. d) Generator with constant internal resistance shunt.

When the photocurrent density is maximum and constant, we see that the photovoltage is small: we have a real power generator. The solar cell is characterized by current leakage from which the existence of shunt resistance ($R_s$). By cons when the photovoltage is maximum and constant, the photocurrent density is low: we have a real voltage generator therefore it has a series resistance of existence ($R_s$) that takes into account the difference between the external voltage and the voltage appears across the junction.

**D. ELECTRICAL PARAMETER**

For the first two electrical parameters, characteristics of the parasitic effects, it is based on previous studies in which the equivalent electrical circuit of the solar cell in the vicinity of the short circuit and that in the vicinity of the open circuit are studied [19]. From these studies, the respective expressions are extracted from the shunt resistance and the series resistance given by the equations (12) and (13):

$$R_{sh} (\omega, S_f, z) = \frac{V_{ph} (\omega, S_f, z)}{J_{cc} (\omega, z) - J_{ph} (\omega, S_f, z)}$$ \hspace{1cm} (12)

$$Rs (\omega, S_f, z) = \frac{V_{oc} (\omega, z) - V_{ph} (\omega, S_f, z)}{J_{ph} (\omega, S_f, z)}$$ \hspace{1cm} (13)

With $J_{cc}$, the short-circuit current and $V_{oc}$, open - voltage circuit.

$J_{cc}$ is obtained with the expression of the photocurrent density by letting the junction recombination velocity to a very high limit ( $S_f \rightarrow \infty$ ). While for $V_{oc}$, expression is used the photovoltage density by letting the junction recombination velocity to a very low limit ( $S_f \rightarrow 0$ ).

**E. BODE DIAGRAMME OF THE ELECTRICAL PARAMETERS**

The Bode diagram [20] a method is developed to simplify the obtaining of the variation of the parameter as a function of frequency. Bode is adopted to the amplitude and phase of the parameter is called Bode amplitude and phase of the Bode.

**F. SHUNT RESISTANCE**

Fig. 4 shows the modulus of shunt resistance versus the logarithm of the modulation frequency for different values of the junction recombination velocity.

![Image](https://via.placeholder.com/150)

**Figure 4** Shunt resistance versus the logarithm of frequency Log($\omega$) for different values of the junction recombination velocity.

$H = 0.03$cm, $L_o = 0.02$cm, $D_o = 26$cm²/s, $z = 0.003$cm, $\tau = 10^{-5}$s, $L = (t.D)^{1/2}$

The shunt resistor does not practice varies to a certain value of the junction recombination velocity called $S_{ph}$, from this value. We observed and showed the powerful of the resistance shunt. In fact, when the junction recombination velocity ($S_{ph}$) increases, the fuits also increase. Then the resistance shunt takes high values giving a good quality for the solar cell. We also note that the resistance shunt augment when the angular frequency increases. Indeed, the high frequencies do not promote good carrier mobility within the base. Then the resistance shunt take increasingly large values to ensure good quality in the solar cell. The Bode diagrammes magnitude to determine the cut-off frequency and validate the equivalent circuit model in figure 5.
Figure 5 Module of the shunt resistance versus the logarithm of modulation frequency:
H = 0.03cm, Lo=0.02cm, Do = 26cm²/s, z=0.003cm, τ= 10⁻⁵s, L= (τ.D)¹/²

Figure 5, we observed the same paces: When ω < ωc, the module of the capacitance is independent of frequency : one has a horizontal level for all curves. More Sf is low over this level is maximum. The magnitude of the Bode diagramme to determine the cut-off frequency and confirm the electric model equivalent. When ω > ωc, the module of the capacitance is significantly decreases to tend asymptotically toward zero. Over the junction recombination velocity (Sf) the greater the module of capacitance is low because the little present minority charge carrier’s pass through the junction: we also enlargement of the space charge region ( scr ) or an extension of the space charge region or a spacing of the electrodes [ 21,22 ] the junction can be considered as a plate of capacitor. The analysis of these figures shows the same curve shapes. For ω < 10⁴ Hz, the modulus of the shunt resistance and series that are independent of ω : this is static regime. For an angular frequency ω > ωc, the electrical parameter of the module believes. This frequency ωc corresponds to a so-called cut-off frequency. It is obtained with the intersection of the extensions of each of the two linear portions of the curve. According to Figure 6 or 7, it is seen that the curves have approximately the same peaks of intersection of two linear parts: thus we have the same cut-off frequency for all curves as the electrical parameter studied ( Rsh or Rs ). The figure 8 or 9 respectively phase diagrams of the Rshunt and Rsérie. For the independent of frequency ω < 10⁴ Hz, the phase of the electrical parameter is zero. By cons in high frequencies 10⁴ Hz < ω < 10⁶ Hz, the phase believed ( fig 6 and fig 8 ) and takes positive values , in this area we have the presence of inductive effect or presence of a coil.

G. PHASE OF SHUNT RESISTANCE

The variation of the phase of the shunt resistor with the modulation frequency is shown in Figure 6 below [12].

It can be seen that the phase of the shunt resistance increases with the increase of the modulation frequency. However, it is observed that the phase of the shunt resistor is always positive. Its horizontal junction solar cell has an inductive behavior, and this inductive reaction is greater for high values of data modulation frequency. We can say that when the modulation frequency is high, the response of the photocell is virtually zero. Very high frequencies block relaxation of the solar cell. It is seen that the junction recombination velocity slightly increases the phase of the shunt resistor.

H. SERIES RESISTANCE

The fig. 7 illustrates the profile of the series resistance of the module as a function of the modulation frequency for different junction recombination velocity values [14, 15].
For any given curve, the series resistance increases with the angular frequency especially beyond $\log (\omega) = 10^5$ cm/s. In effect when the angular frequency increases, the provoked current by the generator (Voc) increases. The series resistance is contrasted advantage in the flow of this current: this causes the increase of series resistance. We also note that the series resistance increases with the junction recombination velocity. Indeed, the high frequencies do not promote good circulation of the holders. This will cause some parking and such holders resulting in an increase of the volume series resistance, surface, interface... conferring resistance to an increase in amplitude globally.

Taking different ranges recombination velocity values at the junction, we expand our study on other electrical parameter to known the capacitance.

I. PHASE OF THE SERIES RESISTANCE

The variation of the phase of the series resistance with the modulation frequency is shown in Fig. 8 [12].

![Figure 8 Phase of the series resistance based on the logarithm of modulation frequency for different values of the junction recombination velocity](image)

It is found that the variation of the phase of the series resistance is a function of the modulation frequency. Therefore, we see that the phase of the capacitance is negative and the phases’ effects outweigh the inductive. However, a slight variation of the phase occurs when the frequency is low of about $10^4$ rad / s, but beyond this value there is a rapid increase in the phase of the series resistance. When the modulation frequency increases, the response of the photocell is very low. It is observed that the applied junction recombination velocity slightly decreases the phase of the series resistance, which does not contribute to the good performance of the solar cell.

### TABLE 1

<table>
<thead>
<tr>
<th>$S_f$ ($p.10^4$ cm.s$^{-1}$)</th>
<th>$R_s$ (Ω.cm$^2$)</th>
<th>$\omega_c$ (Hz)</th>
<th>$R_m$ (Ω.cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.73069</td>
<td>$5.1221 \times 10^5$</td>
<td>x</td>
</tr>
<tr>
<td>1.2</td>
<td>0.73706</td>
<td>$5.1221 \times 10^5$</td>
<td>x</td>
</tr>
<tr>
<td>1.6</td>
<td>0.74978</td>
<td>$5.1221 \times 10^5$</td>
<td>x</td>
</tr>
<tr>
<td>4.8</td>
<td>x</td>
<td>$5.4855 \times 10^5$</td>
<td>8906.3</td>
</tr>
<tr>
<td>5.2</td>
<td>x</td>
<td>$5.4855 \times 10^5$</td>
<td>34444</td>
</tr>
<tr>
<td>5.8</td>
<td>x</td>
<td>$5.4855 \times 10^5$</td>
<td>1.7603 $\times 10^5$</td>
</tr>
</tbody>
</table>

For junction recombination velocities are in the vicinity of the open-circuit, the module of series resistance which is small and almost constant. Then it increases significantly with increasing the junction recombination velocity in the vicinity of short-circuit. In the latter neighborhood, the cut-off frequency is slightly higher than the first.

J. CAPACITANCE

When the solar cell is illuminated, there is generation and diffusion of minority carrier through the Space Charge Region (SCR), which is accompanied by charge storage [14].

The capacity equation is given by the relation 16.

$$C = \frac{dQ}{dV_{ph}}$$

with

$$Q = q.\delta(x)_{x=0}$$

with

$$C = q \times \frac{\partial \delta(x)}{\partial V_{ph}}_{x=0}$$

We will see the variation of the capacitance of the solar cell information of the junction recombination velocity (Sf). In Fig 9, we present the profile of the solar cell of the capacitance according to the angular frequency for different vary of the junction recombination velocities.
The figure 10 has been shown to better monitor the module of the capacitance amplitude to the great values of the junction recombination velocity ($S_f$).

When the junction recombination velocity ($S_f$) goes to zero, the capacitance is maximum and remains practically constant until a $S_{foc}$, for the $S_f$ values above the $S_{foc}$, we note a considerable decrease in the capacitance of the solar cell that eventually cancel to large value of the junction recombination velocity ($S_f$). In fact, the capacitance characteristic of the carrier concentration level in the base of the solar cell. Then for the low junction recombination velocity ($S_f$). There is a little modularity carriers and therefore almost all of the carriers find themselves stoques in the base.

But $S_f$ is greater than the $S_{foc}$, we reach out to the energy; that is to say able to model energy of the carrier’s in a direction to participate in ordered photocurrent. While the base is seen empty its stock very quickly thus reducing the capacitance of the solar cell towards nothingness. We observes a decreases in capacitance solar cell with the angular frequency. Indeed, the pulse not promoting photogenerating carriers, it will induce a decrease in the capacitance of the solar cell [17].

The variation of the phase of the variation of the capacitance with the modulation frequency is shown in Figure 11 [12].

<table>
<thead>
<tr>
<th>$S_f$ = $p \cdot 10^s$ (cm.s$^{-1}$)</th>
<th>C (F.cm$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>0.03445</td>
</tr>
<tr>
<td>1.2</td>
<td>0.03498</td>
</tr>
<tr>
<td>1.6</td>
<td>0.03629</td>
</tr>
<tr>
<td>4.8</td>
<td>2.40970</td>
</tr>
<tr>
<td>5.2</td>
<td>10.68828</td>
</tr>
<tr>
<td>5.8</td>
<td>286.93474</td>
</tr>
</tbody>
</table>

K. PHASE OF THE CAPACITANCE

The variation of the phase of the capacitance with the modulation frequency is shown in Figure 11 [12].
The phase of the Bode diagram of capacitance shows the existence of two levels. For \( \omega < 10^4 \) Hz, the phase of the capacitance is independent of the low values of the frequency. For \( 10^4 < \omega < 10^6 \) Hz, the phase of the capacitance decreases following negative values which confirms the presence of the capacitor.

For lower frequencies to the cut-off frequency (\( \omega_c \)), the modulus of the capacitance of the solar cell and its phase, short-circuit situation, remain almost constant with the angular frequency. We note that the amplitude ratio of the capacitance in short-circuit situation to the open circuit condition is of the order of \( 10^{-3} \); while the phase of the capacitance decreases in short-circuit situation. We get the same capacitance module-like phase and the logarithm of the angular frequency as in figure 12. We are seeing that Fig 12 decreased the amplitude of capacitance with angular frequency. With the law of Beer-Lambert, where the angular frequency increases, the absorption of incident light decreases and it corresponds to a low generation of minority carriers can be stored in the database.

**L. NYQUIST DIAGRAM OF THE JUNCTION RECOMBINATION VELOCITY AT THE ELECTRICAL PARAMETERS**

The figures 13 and 14 respectively show the Nyquist diagrams of the series resistance and shunt resistance.

We note that respectively for the two cases the existence of two characteristic points: For \( \omega \rightarrow 0 \), the imaginary part and the real part of the electrical parameter studied cancel and for \( \omega \rightarrow \infty \), the real and the imaginary of the series resistance (Fig12) increase, same characteristics are noticed on the shunt resistance (figure 13).

Following different junction recombination velocity, we represent the Nyquist diagram of the capacitance in figure 15 and figure 16. We get for all curves of semicircles center. For \( R_p \) good visibility (again called the parallel resistance of the diameter semicircle) and \( R_s \) (series resistance), figure 17 and figure 18 are shown.
We observe in these two cases three phenomena:

- For $\omega \to 0$, the imaginary part of the capacity is zero while the actual is different from zero and corresponds to the capacity $C_0$ in the dark or $R_s$ in the case of a resistive circuit.
- For $\omega = \omega_c$, the imaginary part of the capacity is a negative value when the real is positive and corresponds to a maximum.
- For $\omega \to \infty$, both the imaginary part that the real part of the capacity cancel.

This phenomenon allows us to determine the diameter of the semicircle namely $R_p$ [23,24]. From the Bode and Nyquist capability, we can derive the equivalent circuit that describes the electrical behavior of capacity (fig17). Where $C$ is the capacitance of the capacitor which describes the capacitive effect, the parallel resistance ($R_p$) and the series resistance ($R_s$).

IV. CONCLUSION

A theoretical study has been performed on the junction recombination velocity monofacial silicon solar cell and under monochromatic illumination modulation frequency. This study allowed us to remember the expressions of the global generation rate depending on the type of illumination and expressions of the diffusion coefficient according to some electrical parameters. Our study based on electrical parameters of silicon solar cell, characteristic of parasitic effects. We can say that the great values of the recombination velocity which reflect significant leaks minority charge carrier’s at the junction diminish the effects capacitive and contribute to improving the quality of our solar cell while the frequency drive it, it has a detrimental effect on the diffusion of minority charge carriers which affect the efficiency of the solar cell and consequently on the quality. The capacitance of the space charge region was studied using Bode and Nyquist diagrams. Using the junction recombination velocity concept permits us
to determine solar cell’s electric power for any operating point of the solar cell contrarily to others studies which used the maximal power point tracking (MPPT) control technic characterized by one operating point corresponding to the maximum output power delivered by solar cell.

V. REFERENCES

Optical Performance Investigation of a CLFR for the Purpose of Utilizing Solar Energy in Turkey

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Abstract— This study provides a feasibility analysis of the performance of a compact linear Fresnel reflector (CLFR) to be used in a renewable system for the energy demand in some cities in Turkey. The main idea of this work is to investigate whether it will be beneficial or not when CLFRs are used for energy production in Turkey. For this purpose, the optical performance of a CLFR system is investigated theoretically in six of the cities of different regions. The results obtained show that for residential and even for small size commercial usage of CLFR systems could satisfy a very huge amount of solar energy. When the energy need in different processes like heating, cooling, drying is considered, it is easily said that the collected solar energy by a CLFR system would be enough for energy need in many processes.

Keywords— Solar radiation in Turkey, concentrating solar energy, linear Fresnel reflectors, optical performance, renewable energy systems

I. INTRODUCTION

Today, the World is more dependent on energy than ever. Aside from the extraction and the combustion of fossil fuels having severe effect on human health, the decrease in reserves and the increase in energy prices make the renewable energy systems more popular [1]. Besides, increasing global emissions create a big concern [2]. Therefore, the use of renewable energy grows continually all over the world. For all that, the selection of the correct system for given location is still crucial. A detailed investigation of the system is a must for a considered particular location. Many similar works for different locations have been done in the literature [3-13]. In the referred works, different renewable energy systems have been considered for different locations in the world. Thus, the governments from all over the world put a target for renewable energy use in their own countries [14-29]. By having such targets many countries took big steps in renewable energy production. For instance, 114723 GWh of electricity in Germany came from renewable sources in the first nine months of 2015, which was almost double the amount produced from nuclear sources. Additionally, some electricity prices have decreased from the previous year [14]. Economic expansion, rising per capita income, positive demographic trends and the rapid pace of urbanization have been the main drivers of energy demand, which is estimated to increase by around 6 percent per annum until 2023 in Turkey. The current 70 GW installed electricity capacity is expected to reach 120 GW by 2023 to satisfy the increasing demand in the country [20]. Energy is used both as residential and commercial. It can be used for heating, cooling, drying, lighting and obtaining hot water, process steam, and electricity. For all of the purposes, energy can also be obtained through solar energy. The only concern would be the collected amount of the solar energy for these purposes.

This study provides a feasibility analysis of the optical performance of a compact linear Fresnel reflector (CLFR) to be used in a renewable system for the energy demand in some cities in Turkey. The main idea of this work is to investigate whether it will be beneficial or not when CLFRs are used for energy production in Turkey. For many domestic and even commercial but maybe not industrial applications, the solar concentration ratio of 5-15 would be enough to obtain the required energy. To fulfil the job in this paper, optical performance of a CLFR will be examined in detail.

II. SOLAR ENERGY POTENTIAL AND USAGE IN TURKEY

Turkey is located in a very advantageous geographical location with 7.2 hours/day of annual insolation duration and 3.6 kWh/m²·day of annual solar radiation [30]. Monthly solar energy potential of Turkey is given in Table I.

<table>
<thead>
<tr>
<th>TABLE I MONTHLY AVERAGE SOLAR POTENTIAL OF TURKEY [30]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Months</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>January</td>
</tr>
<tr>
<td>February</td>
</tr>
<tr>
<td>March</td>
</tr>
<tr>
<td>April</td>
</tr>
<tr>
<td>May</td>
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<td>June</td>
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<td>July</td>
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<td>August</td>
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<td>September</td>
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<tr>
<td>October</td>
</tr>
<tr>
<td>November</td>
</tr>
<tr>
<td>December</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
<tr>
<td>Average</td>
</tr>
</tbody>
</table>

Also, solar energy potential according to the geographical regions in Turkey is given in Fig. 1.
Average annual total solar radiation map of Turkey is also given in Fig. 2. However it has been recognized that the existing meteorological data is lower than the actual solar energy data of Turkey. EIE (General Directorate of Renewable Energy) and DMI (Turkish State Meteorological Service) have been taking new measurements since 1992 to determine the more accurate solar energy data. Although the measurements have not been completed yet, the collected data indicates that the actual solar energy radiation values are 20-25% higher than the existing data [30].

Despite it seems the regions south-eastern Anatolia and Mediterranean have got the high solar energy potential in Turkey, in this study, the feasibility of using CLFR systems is evaluated for different provinces in different regions because of the changing insolation hours. For this purpose, it is desired to examine the applicability of a CLFR system in Istanbul city of Marmara region, Izmir city of Aegean region, Konya city of Central Anatolia region, Antalya city of Mediterranean region, Gaziantep city of South-eastern Anatolia and Van city of East Anatolia region. To introduce the solar energy potentials, the average monthly total solar energy (kWh/m²-month), and monthly sunshine duration hours (hours/month) are given in the following figures for the aforementioned cities in the selected regions. Since the solar radiation is not high enough in Black Sea region, this region is excluded in this study. Average monthly total solar energy potential for Izmir is given in the Fig. 3 as,
Energy demand in Turkey is mainly met by imported resources like gas and oil. The changes in the number of capita, energy demand, production and import are shown in Table II. Although Turkey has almost all kinds of energy resources, it is an energy importing country, since these resources are limited. More than half of the primary energy consumption in the country is met by imports and the share of imports continues to increase each year [37]. On the other hand, despite there is an annual potential of over 2600 hours sunshine in Turkey, benefit from solar energy was only about 420 ktoe (about 5 TWh as heat) as of 2007 [38].

<table>
<thead>
<tr>
<th>Year</th>
<th>Capita (million)</th>
<th>Primary Energy (TWh)</th>
<th>Production (TWh)</th>
<th>Import (TWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>71.79</td>
<td>952</td>
<td>280</td>
<td>677</td>
</tr>
<tr>
<td>2007</td>
<td>73.90</td>
<td>1163</td>
<td>317</td>
<td>881</td>
</tr>
<tr>
<td>2008</td>
<td>71.08</td>
<td>1146</td>
<td>337</td>
<td>843</td>
</tr>
<tr>
<td>2009</td>
<td>71.90</td>
<td>1136</td>
<td>352</td>
<td>817</td>
</tr>
<tr>
<td>2012</td>
<td>74.90</td>
<td>1360</td>
<td>355</td>
<td>1035</td>
</tr>
<tr>
<td>2013</td>
<td>75.77</td>
<td>1355</td>
<td>376</td>
<td>1008</td>
</tr>
</tbody>
</table>

It can also be easily said that the demand is tend to increase in the incoming decades. Therefore as a solution for this problem, renewable energy appears to be one of the most efficient and effective solutions for clean and sustainable energy development. Among all, solar power is one of the most promising and more predictable than other renewable sources and less vulnerable to changes in seasonal weather. Turkey has relatively rich solar potential. In spite of such a high potential, solar energy is not widely used, except for flat-plate solar collectors. They are only used for domestic hot water production, mostly in the sunny coastal regions. The electricity generation from the solar energy is realized by photovoltaics (PV) and solar collectors. Unfortunately, PVs have high installing costs; hence, an economical usage of them is not easily available today [39].

### III. OPTICAL CALCULATIONS FOR LINEAR FRENSEL REFLECTORS

A compact linear Fresnel reflector system shown in Fig. 9 consists of flat mirrors forming a parabola-like shape to reflect the incident solar rays onto a receiver tube which are placed on top of the mirror system.

Solar power on a collector-mirror is given as [33];

\[
P = I_b W L \sum_{i=0}^{N} \cos(\theta_i)
\]

Where \(I_b\) is direct normal irradiance (DNI) \(\text{W/m}^2\), \(L\) is the length of the mirror (m), \(W\) is the width of the mirror (m), \(N\) is the number of mirror in the system and \(\theta_i\) is the tilt angle of the \(i^{th}\) mirror. \(i=0\) refers the first mirror (if there is any, otherwise refers the central point of the mirrors) in the centre of the system. All of the geometrical parameters related to a CFLR system are given as in the Fig. 10.
The tilt angle of the \( i \)th mirror is defined as [33]:

\[
\theta_i = \frac{\alpha_T - \beta_i}{2}
\]  \hspace{1cm} (2)

where the transversal solar altitude angle \( \alpha_T \) and the angle \( \beta_i \) are defined as:

\[
\alpha_T = \arctan(\tan(\alpha_s)/\sin \gamma_s)
\]  \hspace{1cm} (3)

\[
\beta_i = \arctan(f/Q_i)
\]  \hspace{1cm} (4)

The angles \( \alpha_s \) and \( \gamma_s \) refer to the solar altitude and solar azimuth angles, \( f \) is the height of the absorber and \( Q_i \) is the distance of the \( i \)th mirror from the centre of the CLFR system. The Sun’s position in terms of the angles \( \alpha_s \) and \( \gamma_s \) is calculated through the following equations as [34, 35]:

\[
\cos \gamma_s = \frac{\sin \delta \cos \varphi - \cos \delta \sin \varphi \cos(\text{HRA})}{\cos \alpha_s}
\]  \hspace{1cm} (5a)

Eq.(5a) is valid when the Local Solar Time (LST) is smaller than 12 or hour angle (HRA) is negative, hence the azimuth angle for LST>12 or HRA>0 is calculated by:

\[
\gamma_s = 360 - \cos^{-1}\left(\frac{\sin \delta \cos \varphi - \cos \delta \sin \varphi \cos(\text{HRA})}{\cos \alpha_s}\right)
\]  \hspace{1cm} (5b)

\[
\sin \alpha_s = \sin \delta \sin \varphi + \cos \delta \cos \varphi \cos(\text{HRA})
\]  \hspace{1cm} (6)

where \( \delta \) is the declination angle of the Sun, \( \varphi \) is the latitude of the location of interest;

\[
\delta = 23.45^\circ \sin\left(\frac{360}{365}(d - 81)\right)
\]  \hspace{1cm} (7)

\[
\text{HRA} = 15^\circ \left(\text{LST} - 12\right)
\]  \hspace{1cm} (8)

In Eq.(7) \( d \) refers to the number of the day of the year and \( \text{LST} \) in Eq.(8) is an adjustment of local time (LT) given as:

\[
\text{LST} = \text{LT} + \frac{\text{TC}}{60}
\]  \hspace{1cm} (9)

\( \text{TC} \) in Eq.(9) stands for time correction factor (in minutes) which accounts for the variation of the \( \text{LST} \) within a given time zone due to the longitude variations within the time zone and also incorporates the Equation of Time (EoT) and they are given as:

\[
\text{TC} = 4(\text{longitude} - \text{LSTM}) + \text{EoT}
\]  \hspace{1cm} (10)

\[
\text{EoT} = 49.87 \sin (2B) - 7.53 \cos B - 1.5 \sin B
\]  \hspace{1cm} (11)

where,

\[
B = \frac{360}{365}(d - 81)
\]  \hspace{1cm} (12)

is resulted in degrees. And \( \text{LSTM} \) in Eq.(10) is the Local Standard Time Meridian (LSTM) which is a reference meridian used for a particular time zone and is similar to the Prime Meridian, which is used for Greenwich Mean Time (GMT) and it is calculated as;

\[
\text{LSTM} = 15^\circ \Delta T_{\text{GMT}}
\]  \hspace{1cm} (13)

where \( \Delta T_{\text{GMT}} \) is the difference of the LT from GMT in hours.

A CLFR mirror system might be in modules. There might be up to 15-20 modules in a collector area. Each of the module length and width of a commercial CLFR can be up to 100 m and 30 m respectively. And the width of a single mirror in a module can be 20 to 75 cm. In this study, three different size CFLRs are considered in the calculations. The number of the mirrors and the height of the receiver in the system are taken as 40 and 1 m respectively. These can be assumed either a standalone CLFR system or a module in a larger system. Their technical specifications are given in the Table III.

### TABLE III

**The Technical Specifications of the CLFR Modules**

<table>
<thead>
<tr>
<th>Modul</th>
<th>Module length (m)</th>
<th>Mirror width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td>M2</td>
<td>4</td>
<td>0.20</td>
</tr>
<tr>
<td>M3</td>
<td>10</td>
<td>0.3</td>
</tr>
</tbody>
</table>

When the incoming daily average monthly total solar radiation is considered, the annual total solar energy collected by a tracking CFLR system in the aforementioned cities are calculated through all the equations given above and presented as in the Table IV.

### TABLE IV

**Monthly Average Annual Total Solar Energy**

<table>
<thead>
<tr>
<th>City</th>
<th>M1 (MWh)</th>
<th>M2 (MWh)</th>
<th>M3 (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Istanbul</td>
<td>2.92</td>
<td>41.77</td>
<td>150.92</td>
</tr>
<tr>
<td>Izmir</td>
<td>3.47</td>
<td>49.95</td>
<td>180.73</td>
</tr>
<tr>
<td>Antalya</td>
<td>3.63</td>
<td>48.01</td>
<td>173.43</td>
</tr>
<tr>
<td>Konya</td>
<td>3.44</td>
<td>49.22</td>
<td>177.98</td>
</tr>
<tr>
<td>Gaziantep</td>
<td>3.60</td>
<td>52.89</td>
<td>191.39</td>
</tr>
<tr>
<td>Van</td>
<td>3.51</td>
<td>52.61</td>
<td>191.34</td>
</tr>
</tbody>
</table>

As it can be shown in the Table IV that as the mirror size changes, the collected solar energy changes dramatically. Also, it can be noticed that although they are the cities in different locations from north to south and west to east, there are no big differences in collected energy in Turkey.

**IV. CONCLUSIONS**

Turkey is due to take place in the Sunbelt, despite having high solar energy potential and sunshine hours; this resource is used only in low temperature applications. Concentrating solar energy systems are very promising on making use of this abundant energy. Among them, the relatively low cost and high efficient CLFR systems might offer a very huge advantageous in solar energy use.

In this study, optical performance of CLFR systems in different size is examined for different cities in Turkey. Results show that for residential and even for small size commercial use of CLFR systems could satisfy a very huge amount of solar energy. When the energy need in different processes like heating, cooling, drying is considered, it is easily said that the collected solar energy by a CLFR system would be enough for energy need in many processes. This kind of feasibility studies can help to those who want to make investment in solar energy sector as well as those who want to study further in the subject.

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Abstract: Energy harvesting from the surrounding environment has been a superior way of eliminating the burden of having to replace depleted batteries in wireless sensor networks (WSNs), thereby achieving a perpetual lifetime. However, the ambient energy is highly time-variable and depends on the environmental conditions, which raises the need to design new approaches for predicting future energy availability. This paper presents a performance evaluation and comparison of three recently-proposed solar energy prediction algorithms for WSNs. In order to provide an accurate performance of the algorithms, real-world measurements obtained from a solar panel were considered. Also, the performance characteristics of the algorithms in four seasons – winter, spring, summer and autumn – were demonstrated. To do this, a month in each season was selected for performance comparison, discussing the performance of the algorithms in each season.

Keywords: wireless sensor networks; energy harvesting; solar energy; EWMA.

I. INTRODUCTION

Wireless sensor networks (WSNs) are composed of a collection of sensor nodes designed to perform a common duty and which have the tasks of sensing, processing and communicating data, aiming to deliver it to a remotely-located central point [1]. The sensor nodes are often powered by limited-energy sources, typically small batteries. This makes energy efficiency a vital criterion in the development of WSNs, so the main emphasis has been placed on prolonging the lifetime of WSNs. A sensor node is equipped with four components as depicted in Fig. 1: (1) a sensing unit to detect environmental data such as temperature; (2) a micro-processor to process the data; (3) a radio for communication between the sensor nodes; and (4) an energy unit to supply energy to all the components. It is well-understood that data communication in a sensor node consumes the most energy. Therefore, communication between the sensor nodes has to be managed in an efficient manner. To control the transmission medium in a WSN effectively, medium access control (MAC) protocols are developed to reduce the energy consumption due to inefficient data communication (for example, by collision). There are huge numbers of MAC protocols specifically proposed for WSNs which minimize energy wastage as well as enhancing the channel performance (for example, throughput, delay and fairness) [2, 3]. However, such a WSN system will eventually fail to operate because of the limited energy supply.

In order to handle the inevitable energy depletion in WSNs, energy harvesting (EH) from the environment is an alternative technique to ensure an unlimited energy source. In this technique, each sensor node can harvest energy continuously from its surrounding environment through an EH device. The main purpose is to extract the environmental energy and convert it into electricity to power sensor nodes. The major sources of existing environmental energy for WSNs are solar, wind, vibration and thermal. In order to enable sensor nodes to benefit from EH technology, a new type of sensor node equipped with an EH unit has been developed to perpetuate the lifetime of WSNs [4]. Fig. 2 presents an example architecture of an EH sensor node with the sun as the energy source, a solar panel to produce energy from the sun, and a super-capacitor to store the harvested energy.
EH sensor nodes potentially provide a perpetual lifetime by exploiting the ambient energy. It should therefore be noted that the fundamentals of MAC protocols that will be developed for energy harvesting WSNs (EH-WSNs) will be re-considered to mitigate the uncertainty of amount of ambient energy over time. This is because ambient energy is highly dependent on environmental conditions and is time-variable. The ambient energy can be harvested using varying ratios at different time slots of a particular day. The main task of new MAC protocols is to maintain the performance of a network at an acceptable ratio with respect to the changing available rate of energy to be harvested. Currently, the design of MAC protocols for EH-WSNs is a fiercely-debated topic and an on-going research area. A number of MAC protocols proposed for EH-WSNs have been surveyed in detail in [5]. This survey explicitly highlights that existing MAC protocols should comfortably meet the energy neutral operation (ENO) condition in which the amount of energy generated must always be greater than the energy consumed within a particular time duration. The nodes which satisfy the ENO condition are assumed to operate perennially. In these protocols, a node is allowed to start transmission as long as it stores sufficient power in its battery.

Many of the current MAC protocols do not consider future energy availability as they only consider current residual energy level as discussed above. The future energy level, however, may change dramatically resulting in some nodes facing temporary energy shortages. This can cause significant problems, such as some important information might be transmitted very late or get lost. Therefore, future MAC protocols should arrange the transmission policies based on the energy generation ratio. Careful prediction of future energy levels opens a new perspective.

The aim of this paper is to study the solar energy prediction algorithms proposed for EH-WSNs, focusing particularly on the performance of the algorithms using real measurements. Solar energy was chosen for this study as it is the most appropriate energy source for EH-WSNs due to its high energy density. We selected three recent prediction algorithms: the exponentially-weighted moving average (EWMA) [6], the accurate solar energy allocation (ASEA) [7] and the weather-conditioned moving average (WCMA) [8]. These approaches had been previously tested in short-term scenarios (a few days) in which the actual performance of the approaches may not have been reflected. To avoid this, we obtained real measurements from [9] for the second month of each season in 2015. Also, the basic operations of the approaches will be described in detail in the following section. It is believed that this study will provide an insight into future research directions in the relevant area.

II. SOLAR ENERGY PREDICTION APPROACHES

A. Exponentially-Weighted Moving Average

The exponentially-weighted moving average (EWMA) is the main approach which has inspired the design of many prediction algorithms in the literature. The fundamental aim of EWMA is to benefit from the daily cycle in solar energy by adapting to seasonal variations. The 24-hour day is divided into slots of equal length, such as 24 one-hour slots. The energy in each slot is predicted based on an exponentially increasing/decreasing rule given by Eq. (1).

EWMA uses historical information of the energy generation pattern. For this purpose, the last amount of harvested energy (R) and estimated energy (E) by EWMA are summed with a weighting factor, \(0 < \alpha < 1\), arranging the importance of the R and E. A high value of \(\alpha\) corresponds to less importance of the last-harvested energy and vice versa.

\[
E(d, n) = \alpha E(d-1, n) + (1 - \alpha) R(d-1, n)
\]  

where \(d\) represents the present day and \(n\) is the slot identifier. One of the most important features of EWMA is its high adaptability for seasonal weather variations. The efficiency of EWMA in terms of time taken to adapt to such seasonal change depends on the duration of weather variation and an accurate choice of \(\alpha\). Fig. 3 presents an illustrative example for predicting energy using two different \(\alpha\) values. In this example, the energy estimation in slot 2 is performed in a case when the weather condition changes abruptly. The amount of harvested energy continues to be four times greater than the estimated energy. An \(\alpha\) value of 0.5 exhibits slower adaptability than an \(\alpha\) value of 0.3. This is because, as discussed above, smaller \(\alpha\) values take the latest real energy measurement into consideration more aggressively. After a specific time period, both \(\alpha\) values start to provide accurate overall predictions.

The major disadvantage of EWMA is its vulnerability to temporary changes. For example, the example presented below shows that the energy expectation on the day after \((T+6)\) day will certainly be a value close to 40. If, however, contrary to expectation, the harvested energy on this day is significantly higher/lower than the expected energy, EWMA produces highly inaccurate results. It is therefore crucial to consider the solar energy conditions on the current day.
is sample and the corresponding sample prediction equation. Also, the mean value of the values which are stored in a matrix, conditions.

Another algorithm which the current weather conditions into consideration.

Fig. 3 An example process of EWMA, α = 0.5 and α = 0.3.

B. Accurate Solar Energy Allocation

Accurate solar energy allocation (ASEA) attempts to allocate the harvested energy equally to each slot in a particular day for EH-WSNs regardless of the amount of generated energy in any slot. To do this, it modifies the EWMA to cope with the drawback of EWMA. The basic idea of ASEA is to look at the present conditions by adding a new parameter, \( \psi \), to Eq. (1). This parameter represents the ratio between the actual amount of energy harvested and the energy estimated by EWMA in the previous slot. The modified equation is therefore given as:

\[
\hat{E}(d, n) = E(d, n) \cdot \psi \quad \text{where} \quad \psi = \frac{R(d, n-1)}{E(d, n-1)} \tag{2}
\]

C. Weather-Conditioned Moving Average

The weather-conditioned moving average (WCMA) is another algorithm which takes the current weather conditions into consideration. WCMA collects past energy values which are stored in a matrix, \( E(i, j) \), where \( j \) is a sample on the \( i^{th} \) day. One of the main distinctive features of WCMA is that it incorporates previous samples into the prediction equation. Also, the mean value of the corresponding samples from previous days is calculated. Therefore, the prediction equation related to the previous sample and the mean value of the sample given by Eq. (3) is:

\[
E(d, n+1) = \alpha E(d, n) + (1 - \alpha) M(d, n+1)GAP \tag{3}
\]

where \( E(i,j) \) is the energy values taken from the \( E \) matrix and \( M(i,j) \) is the mean value of the sample. \( GAP \) is a new weighting factor introduced in order to reflect current weather conditions. The mean value of the sample is calculated as follows:

\[
M(d, n+1) = \frac{\sum_{i=1}^{D} E(i, n + 1)}{D} \tag{4}
\]

To compute the \( GAP \) value, a vector, \( V = [V_1, V_2, ..., V_K] \), is first defined. The elements of the \( V \) vector are the previous samples in the same day, each of which represents the ratio of the the harvested energy to the mean value. Hence, a value less than 1 means that the harvested energy is less than the mean:

\[
V_k = \frac{E(d, n-K+k)}{M(d, n-K+k)} \tag{5}
\]

Once the elements of the \( V \) vector are calculated, these values are weighted according to their distance from the actual sample. This is to give more importance to closer samples and less importance to far samples. To do this, a vector, \( P = [p_1, p_2, ..., p_K] \), is defined as follows:

\[
p_k = \frac{k}{K} \tag{6}
\]

The weighting factor, \( GAP \), is finally computed as:

\[
GAP = \frac{V \cdot P}{\sum P} \tag{7}
\]

The size of the \( E \) matrix is an important parameter to establish. Considering the limited memory in sensor nodes, the size should be carefully selected whilst meeting the memory constraint. Also, the value of \( K \) which is the number of past samples to weight should be carefully adjusted. It must be large enough to observe the current weather condition but also small enough not to consider some samples that do not have any impact on present conditions, such as night values.

In the original paper on WCMA, from an analysis of the choice of dimensions of the \( E \) vector, the value of \( K \) was calculated. The best values found to minimize the prediction error were \( D = four \) days, \( K = three \) samples. These values were used in all the experiments in this current study. Also, an \( \alpha \) value of 0.7 was the optimum value that gave the minimal error.
III. PERFORMANCE EVALUATION

The performances of the EWMA, ASEA and WCMA schemes were compared using real solar panel outputs in the second month of each season of 2015. The purpose of this was to demonstrate the behavior of the performance throughout the year. Fig. 4 presents the performance of the schemes in terms of prediction error ratio (PER). Each point in the curves represents the average of 30 days. Additionally, Fig. 4e depicts the prediction accuracy in January.

It is obvious that the weighting factor, α, had a significant effect on the prediction accuracy for all three schemes. EWMA and ASEA exhibited a similar performance as ASEA is an extension of EWMA. ASEA achieved a better performance than EWMA because ASEA reflects the latest current energy condition. The results tell us that high and low values of α in EWMA and ASEA provide highly inaccurate predictions, whereas medium values of $0.4 < \alpha < 0.9$, ensure more accurate predictions. In EWMA and ASEA, therefore, the estimated average energy (E) and real measured energy (R) (see Eq. (1)) should contribute closely to achieving accurate predictions. However, WCMA provided significantly high accurate predictions at low values of α. Eq. (3) clearly shows that low values of α mean a low contribution of energy in the previous slot. In other words, the mean of the energy in association with the current energy condition has more influence on the prediction. Hence, WCMA with small values of $\alpha$, $\alpha < 0.6$, predicts energy more accurately than EWMA and ASEA, but the high values of α make WCMA the worst scheme. As discussed above, EWMA would not be a good choice in frequently changing weather conditions. In January, the weather changes almost daily, as shown in Fig. 4e. The PER of EWMA is close to 0.6 (60%) at an α value of 0.7. When the weather does not change frequently, as in July, the PER reduces to 0.18. In all cases, ASEA has a similar curve to that of EWMA improving the PER. In WCMA, on the other hand, the contribution of energy in the previous slot of the same day does not actually seem to be relevant as the PER rises with the increasing influence of the previous slot’s energy value.

We conclude that WCMA is the best prediction algorithm as it benefits from the long-term current solar energy condition, provided that α has a small magnitude. EWMA can be considered as a baseline scheme which takes seasonal solar energy into consideration, resulting in high incorrect predictions with frequently changing solar conditions. ASEA considers only the latest solar energy condition which causes high inaccurate predictions in particular in times of temporary weather changes.

IV. CONCLUSIONS

Three popular solar energy prediction schemes have been studied in this paper. The performance of the schemes in terms of the prediction error using real solar panel outputs has been presented and compared. It has been shown that the level of ambient energy to be harvested is highly time-variable, so it is crucial to consider current weather conditions when predicting energy, particularly in changing diurnal weather conditions. Also, the weighting
factor, $\alpha$, in all three schemes plays an important role in enabling accurate prediction. The main conclusion of this study for high accurate energy prediction is to reconcile the past energy generation profile with the current energy pattern.

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Methanol Combustion Simulation via CFD

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Abstract— Methanol combustion can take place in various mediums ranging from internal combustion engines to burners and such. Consequently combustion efficiency and the dimensional system characteristics vary from system to system. Recent researches are going on to identify these aforementioned characteristics. Present paper is a part of such effort. A combustion domain representing the geometrical parameters of a burner was modelled and governing equations for combustion process were selected in a commercial CFD solver. Results constitute base for future work focusing on a similar burner performance. Static pressure distribution, mesh structure, temperature distribution, turbulence intensity, density distribution and velocity vectors are presented in both 2D planes and 3D domain. Results indicate the importance of combustion volume entrance design. There are dead regions adjacent to the combustion volume entrance. It is proposed that a new entrance region should be designed.

Keywords— CFD, Combustion, Fluid Dynamics, Methanol, Simulation

I. INTRODUCTION

Porous medium as an alternative to conventional burners attracts industrial and scientific communities. Their compact and complex inner structure leads to efficient burning of the fuels while its general geometry from outside can be adapted literally to any volume. Figure 1 is provided in order to give an idea for a porous medium burner.

Methanol combustion can take place in various mediums ranging from internal combustion engines to burners and such. Consequently combustion efficiency and the dimensional system characteristics vary from system to system. Recent researches are going on to identify these aforementioned characteristics.

There are remarkable studies in the literature about modeling porous combustion mediums and fuels such as methanol [1-3]. These studies focus on geometrical modelling of the medium, proper models for the flow and combustion and comparison of the obtained results with literature and experimental results.

As a preliminary evaluation tool, CFD was utilized in case of a cylindrical body representing a porous metal matrix burner. Methanol was simulated with air as an ideal gas. Boundary conditions were selected according to the real application operational parameters of the so called porous metal matrix burner. By this way, static pressure distribution, velocity profiles, density of the fluid, enthalpy, total pressure, turbulent kinetic energy and dynamic viscosity changes were presented versus radius of the examined body. Fluent was employed for the modelling and calculation software. A similar numerical work was conducted by Abdulkarim [4] and it can be referred for the results of a similar study.

II. ANALYSIS

Ansys Fluent was used for the computational analysis. Cartesian coordinates were used for the computational domain but curvilinear adapted mesh was utilized. This doesn’t lead to any complexities in the major fraction of the computational domain and the CFD code can handle this situation. Air was selected as the fluid and thermo physical properties were selected accordingly.

A fine mesh setting was applied to the cylindrical porous medium model geometry and the general view of the mesh structure is provided in Figure 2. k-ε turbulence model was utilized as a general and justified turbulence model for the examined geometry. Since internal boundaries are avoided for the present preliminary investigation, the utilization of the k-ε turbulence model was appropriate. The governing equations for this model are not provided here for the convenience of the space however as a well established and validated model, governing equations can be found easily in the literature.

Fig. 1 Combustion in a porous medium burner
III. RESULTS

Since the symmetry exists in the analysis, mainly axial change is presented and evaluated here. The graphics are presented on a 2D plane and in a 3D volume. The quantitative values can be extracted from the color scale which also includes and indicates numbers.

Due to the energy dissipation by the friction, static and total pressure values decrease in the flow direction. Pressure gradient in the axial direction occurs as the maximum pressure value exists at the entrance or in other words inlet of the medium. Quantitative results are presented for static pressure in Figure 3, Static Temperature in Figure 4, Contours of static temperature in Figure 5, Velocity vectors in Figure 6, Contours of velocity magnitude in Figure 7, turbulent kinetic energy distribution in Figure 8 and Density distribution in Figure 9 respectively.

As the fluid enters to the computational domain, a compression effect takes place and this leads to an increase at the initial part of the inlet. As the flow continues to the inlet neck, velocity increases and the static pressure is converted to kinetic energy and hence the value of the static pressure decreases here. When further continuing on the axial direction, static pressure recovers and has its final value.

3D domain in respect of the temperature quantitative results can be confusing since the wall has a dominant value comparing to the axis of the computational domain. The dominant temperature value at the boundaries is about 1300 K. Due to the dead points and relatively poor conduction at the corners, temperature value is about 940 K at the corners. Since the flame temperatures are much higher, these temperatures are expected at the boundaries. Considering the radiation, porous burner can actively transfer the heat via radiation. However the present work doesn’t contain boundaries for porous extensions, so the real application will lead lower temperatures at the outer boundaries.
When a 2D plane inserted in the 3D domain in order to inspect temperature distribution contours for the computational domain, one can see that the fluid temperature can reach approximately 1720 K at the axis of the medium. Since the present work doesn’t contain any solid boundaries at the center of the volume, this temperature can be regarded as the flame temperature. With the effect of the axial conduction and diffusion this maximum becomes lower as the field of interest advances more through dead points. We can see the effects of flow separation at close proximity of the adjacent edges perpendicular to the inlet. The lowest temperatures can be observed here because of the flow separation. However real world application will differ in this respect because of the axial conduction, i.e. reverse heat transfer.

Due to the conversion of the static pressure to the dynamic pressure, in other words to velocity, at the minimum diameter in the inlet, maximum velocity can be observed here in Figure 7. The maximum temperature seems to be around 24.1 m/s. At the first quarter of the volume the velocity decreases to 6.4 m/s and then gets a more moderate value around 2-4 m/s. We can see a dead point at the farthest point in axial direction.

Turbulence kinetic energy gives information of local fluctuations. A laminar and un-mixing flow would lead to a minimum turbulence kinetic energy pattern. Considering this information, Figure 8 indicates the locations of the shear layers. A relatively low turbulence kinetic energy, namely \(2.21 \text{ m}^2/\text{s}^2\) can be observed, so we can think that mixing process is not strong. However one should consider that real application won’t contain such a structure since there will be secondary boundaries due to the porous structure. Symmetry can also be seen for turbulence kinetic energy. At the inlet, a flow structure similar to the pipe flow can be observed due to the developing flow in the presence of close walls.
Density increases at the close proximity of the walls of the cylindrical body due to the compression in the presence of a solid obstacle. Considering the gas fluid, compression yields change in the density of the fluid. Also maximum enthalpy occurs near the outlet of the cylindrical body.

**IV. CONCLUSION**

The flow patterns and general flow conditions yielded a favorable situation in respect of a medium designed as a burner. Since the real application combustion volume will have several inner boundaries due to the porous structure, flow separations and irregularities will diminish and/or become smaller in scale.

Heat transfer will be superior with a porous inner structure by generally speaking. Since conduction, convection and radiation will exist, the burner can act a preferable device. Convection is expected to be the least effective mechanism in the porous volume comparing to the radiation and conduction. General geometry of the porous medium model is found to be favorable in respect of its operational flow conditions. Further work can be undertaken in order to achieve a more realistic geometry and numerical combustion can be included into the analysis.

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An analytic assessment of ship energy efficiency in
maritime transportation engineering.

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Abstract—Energy efficiency is one of the core topics in maritime
transportation industry as the ships consume a large amount of
energy due to nature of work. Environmental awareness is
another critical perspective to improve energy efficiency due to
greenhouse gas emission from the ships. Therefore, maritime
regulatory bodies adopted Ship Energy Efficiency Management
Plan (SEEMP) to provide necessary improvement of energy
efficiency on-board ship [1]. The aim of this paper is to assess
energy efficiency of ships analytically to enhance performance of
ships as well as minimize environmental pollution. In this
case, the paper adopts Buckley extension based analytic
hierarchy process (AHP) under fuzzy sets environment to
enhance the sensitivity. Besides its theoretical insight, the paper
has practical benefits to shipowner who can seek to improve the
energy efficiency aspects for not only ships but also company-
wide.

Keywords—Ship energy efficiency, fuzzy AHP, maritime
transportation, energy improvement.

I. INTRODUCTION

Although maritime transportation is a relatively efficient
mode of cargo carriage, ship consumes a large quantity of
energy when compared to other modes of transportation.
Particularly, greenhouse gas emission (GHG) largely pollute
environment due to the high sulphur content of fuel. The
International Maritime Organisation (IMO) was adopted a set
of rules such as Energy Efficiency Design Index (EEDI) and
Ship Energy Efficiency Management Plan (SEEMP) in order
to control aforementioned problem and improve ship
efficiency by better management. Each shipowner is
responsible to establish a SEEMP on the basis of ship fleet
operations, management and energy consumption. The
expectation from the shipowners or operators is to develop a
regular planning, implementation, monitoring and self-
evaluation of SEEMP. Figure 1 shows basic process of
SEEMP [2]. Accordingly, a good planning is needed to
establish SEEMP. Therefore, shipowner must review energy
consumption and procedures exercised on-board fleet ships. In
the second step, the plan, which has been developed by
reviewing current deficiencies, must be implemented. Then, a
short or long term monitoring must be performed to assess
performance. The final step is to conduct self-evaluation
whether how effective developed SEEMP is working. Hence,
the outcomes assist shipowners or operators to understand the
level of improvement about ship energy efficiency.

Since assessment of ship energy efficiency is of paramount
concern in maritime transportation, there have been limited
studies undertaken so far. Most of them give general
perspective and barriers with respect to the ship energy
efficiency. For instance, [3] discussed ship energy efficiency
management in a general perspective by proposing a total
solution approach. Another study was performed to compare
SEEMP to ISO 50001 and International Safety Management
(ISM) code [4]. The authors discussed gaps among the codes
and proposed recommendations to reduce CO2 emissions in
maritime transportation. Likewise, another study was
conducted to discuss barriers about energy efficiency in
maritime transportation industry [5]. The authors show that
the project management, communication, responsibilities and
resources are the key areas where most of barriers are placed.
Another study related to potential barriers to energy efficiency
in shipping was performed to deal with them [6]. A rational
framework provides the ability to cope with potential barriers
in energy efficiency management is proposed to improve
energy efficiency. Furthermore, a triangulated approach to
investigate the potential problem in ship energy efficiency was
introduced to improve implementation of energy efficiency in
maritime transportation industry [7]. The authors performed a
comprehensive survey with shipping company to obtain
energy efficiency data.

In the view of the ship energy efficiency, some scientific
researches have been performed, however those dedicated to
measure energy efficiency have remained limited. This paper
aims to evaluate the critical performance indicators associated with ship energy efficiency. To achieve this purpose, Buckley extended AHP under fuzzy environment is employed. Accordingly, this paper is organised as follows. This section presents a motivation behind the study and basic literature reviewing about analysis of ship energy efficiency. Section 2 defines the theoretical framework of Buckley extension based Fuzzy-AHP. Section 3 shows how proposed approach is applied to measure ship energy efficiency. The final section provides conclusion note and future studies.

II. METHODOLOGY

In this section, Buckley extension based Fuzzy-AHP method is expressed step by step to assess ship energy efficiency in maritime transportation engineering.

A. Buckley Extension Based Fuzzy-AHP

Analytic Hierarchy Process (AHP) is well-known multi-criteria decision-making (MCDM) tool to solve complicated decision problems. It was first introduced by Saaty [8]. The method suffers one major limitation: it does not cope with uncertainty and vagueness from the subjective perception and experience of humans in the decision-making process. To overcome this limitation, the method is extended with fuzzy logic, which presents interval judgements rather than fixed values [9]. Triangular fuzzy numbers (TFNs) are adopted to evaluate the vagueness of the linguistic evaluation quantifies the judgement value of linguistic expression. (l|m, m|u) or (l, m, u) is the illustration of TFN and stand for the smallest possible value, the most promising and the largest possible values [10]. In this context, equation (1) shows TFN accordingly.

$$
\mu\left(\frac{x}{\tilde{M}}\right) = \begin{cases} 
0, & x < l \\
\frac{(x-l)/(m-l)}{1}, & 1 \leq x \leq m \\
\frac{(u-x)/(u-m)}{m}, & m \leq x \leq u \\
0, & x > u 
\end{cases} \quad (1)
$$

Since there are wide range of fuzzy comparison matrices such as a fuzzy Logarithmic Least Squares Method (LLSM) [11], geometric mean method [12], a fuzzy Least Squares priority Method (LSM) [13], a fuzzy Preference Programming Method (PPM) [14] introduced in different domains, this paper takes benefit of Buckley’s Fuzzy-AHP algorithm to determine criteria weights. The main advantages of the method are to provide not only a unique solution to the reciprocal comparison matrix but also relatively simple calculation. The main steps of the Buckley extended Fuzzy-AHP method are expressed as follows [12].

Step 1. In this step, a pairwise comparison matrix (equation 2) in the hierarchical structure is established. Accordingly, linguistic terms that are provided in equation (3) nominated to construct pairwise comparison matrix.

$$
\tilde{M} = \left[ \begin{array}{cccc} 
1 & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\
\tilde{a}_{21} & 1 & \cdots & \tilde{a}_{2n} \\
& \ddots & \ddots & \ddots \\
\tilde{a}_{nl} & \tilde{a}_{n2} & \cdots & 1 
\end{array} \right] = \left(1/\tilde{a}_{21} \begin{array}{cccc} 
1 \\
\vdots \\
\tilde{a}_{nl} \\
\tilde{a}_{n2} \\
1 
\end{array}\right) \quad (2)
$$

where,

$$
\tilde{a}_{ij} = \begin{cases} 
i, 3, 5, 7, 9 & \text{criterion } i \text{ has less importance to criterion } j \\
1, \tilde{i}^{-1}, \tilde{5}^{-1}, \tilde{7}^{-1}, \tilde{9}^{-1} & \text{criterion } i \text{ has relative importance to criterion } j 
\end{cases} \quad (3)
$$

Step 2. In this step, a consistency of data is acquired by using equation (4, 5 and 6). If the consistency ratio (CR) is found equal or smaller than 0.10, the expert judgement is considered as reasonable and consistent [15-16]. The CR is calculated to evaluate the consistency of the comparison matrix in classical AHP. However, the outcomes of fuzzy AHP are fuzzy numbers of linguistic judgments. Hence, it is necessary to perform a defuzzification technique. In this paper, the center of area defuzzification method is used because of its simplicity [17].

$$
Cl = \frac{\lambda_{\text{max}} \cdot n - m}{n-1} \quad (4)
$$

$$
\sum_{i=1}^{n} a_{ij} w_i = \lambda_{\text{max}} w_i \quad (5)
$$

$$
CR = \frac{Cl}{RI} \quad (6)
$$

Step 3. In this step, it is used a geometric mean method in order to identify the fuzzy geometric mean. Equation (7) shows notation accordingly.

$$
\tilde{r}_i = \left(\tilde{a}_{1i} \times \tilde{a}_{2i} \times \cdots \times \tilde{a}_{ni}\right)^{1/n} \quad (7)
$$

In the equation, $\tilde{a}_{ii}$ is a fuzzy comparison value of criteria.

Step 4. In this step, fuzzy weights of each criteria is determined by using equation (8) where $\tilde{w}_i$ denotes fuzzy weight of $i^{th}$ criteria and indicated by

$$
\tilde{w}_i = \tilde{r}_i \times \left(\tilde{r}_1 + \tilde{r}_2 + \cdots + \tilde{r}_n\right)^{-1} \quad (8)
$$
Step 5. In the final step, centre of area (COA) method is employed to ascertain the best non-fuzzy performance (crisp weight) of each criteria. In this context, equation (9) is used.

\[ BNPw_i = \frac{[(uw_i - lv_i) + (mw_i - lv_i)]}{3 + lw_i} \quad (9) \]

III. EVALUATION OF SHIP ENERGY EFFICIENCY

In this section, the fuzzy-AHP method is applied to evaluate energy efficiency of ships in maritime transportation to enhance ship performance.

A. Problem Definition

Energy efficiency management poses a major challenge for shipowner and operators since bunkering cost is one of the critical items in running cost of ship. Therefore, shipowners and operators monitor performance and improve their energy efficiency for ship fleets. There are a couple of parameters to initially evaluate improvement of energy efficiency. In the long term, energy efficiency improvement can be achieved through the integration of innovative technologies. Hence, it is essential to assess aforementioned parameters considering critical factors that affecting the energy efficiency of a ship’s operation.

B. Ship Energy Efficiency Assessment

In order to implement an effective SEEMP, critical parameters must be analysed and evaluated based on planning, implementation, monitoring and self-evaluation process. The ship fleetwide analysis is capable of providing useful performance indicators such as voyage planning, ship speed optimisation, ship handling, propeller cleaning, hull coating, etc. A sensitive comparison evaluation is required by shipowners or operators for performance assessment in effective manner. In this context, Table 1 shows critical performance indicators (CPI) to understand current energy efficiency and to make improvements through entire ship fleet.

<table>
<thead>
<tr>
<th>No</th>
<th>CPI</th>
<th>Category</th>
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<tbody>
<tr>
<td>CPI1</td>
<td>Voyage planning</td>
<td>Fuel Efficiency operations</td>
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<tr>
<td>CPI2</td>
<td>Ship speed optimization</td>
<td>Fuel Efficiency operations</td>
</tr>
<tr>
<td>CPI3</td>
<td>Propeller cleaning</td>
<td>Propulsion system</td>
</tr>
<tr>
<td>CPI4</td>
<td>Hull coating</td>
<td>Hull maintenance</td>
</tr>
<tr>
<td>CPI5</td>
<td>Keel cleaning</td>
<td>Hull maintenance</td>
</tr>
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<td>CPI6</td>
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<td>Optimized ship handling</td>
</tr>
<tr>
<td>CPI7</td>
<td>Trim and ballast optimization</td>
<td>Optimized ship handling</td>
</tr>
<tr>
<td>CPI8</td>
<td>Slow streaming</td>
<td>Optimized ship handling</td>
</tr>
<tr>
<td>CPI9</td>
<td>Hull design</td>
<td>Hull maintenance</td>
</tr>
</tbody>
</table>

In order to assess critical performance indicators for evaluating ship energy efficiency, a comprehensive survey was carried out with three marine experts who have been working for a prestigious shipping company. The marine experts profile includes marine engineers and superintended. The average experience in the field is about fourteen years. Each expert was asked to compare each CPI according to the Saaty’s 1-9 scale, which is provided in Table 2.

<table>
<thead>
<tr>
<th>Table II</th>
<th>TRIANGULAR FUZZY SCALE AND LINGUISTIC TERMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saaty's scale</td>
<td>Definition</td>
</tr>
<tr>
<td>1</td>
<td>Equally Importance (E)</td>
</tr>
<tr>
<td>3</td>
<td>Moderately Importance (MI)</td>
</tr>
<tr>
<td>5</td>
<td>Strongly Importance (SI)</td>
</tr>
<tr>
<td>7</td>
<td>Demonstrated Importance (DI)</td>
</tr>
<tr>
<td>9</td>
<td>Extreme Importance (EI)</td>
</tr>
<tr>
<td>2</td>
<td>Intermediate values between two adjacent judgments</td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

In the view of Saaty’s scale, three expert evaluated CPIs. Table 3 shows pairwise comparison matrix created by three marine experts for each CPI.

<table>
<thead>
<tr>
<th>Table III</th>
<th>PAIRWISE COMPARISONS FOR THREE MARINE EXPERTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI1</td>
<td>CPI2</td>
</tr>
<tr>
<td>E1</td>
<td>E</td>
</tr>
<tr>
<td>CPI2</td>
<td>E</td>
</tr>
<tr>
<td>CPI3</td>
<td>E</td>
</tr>
<tr>
<td>CPI4</td>
<td>E</td>
</tr>
<tr>
<td>CPI5</td>
<td>.</td>
</tr>
<tr>
<td>CPI6</td>
<td>.</td>
</tr>
<tr>
<td>CPI7</td>
<td>.</td>
</tr>
<tr>
<td>CPI8</td>
<td>.</td>
</tr>
<tr>
<td>CPI9</td>
<td>.</td>
</tr>
</tbody>
</table>

After aggregated three experts’ assessment, equations (1-9) are used to calculate priority weight of each critical performance indicator. In final step, defuzzification is performed by adopting equation (8) to get crisp value of each CPI. The consistency ratio (CR) can be found 0.1049 which is in acceptable limit. Hence, the marine expert judgements inserted in comparison matrices are found reasonable. Accordingly, Table VI illustrates defuzzified and normalised importance weights of CPIs.
In the view of importance weights of CPIs, hull design is one of the crucial indicators in maritime transportation industry from the point of ship energy efficiency since it may considerably affect effectiveness of ship types, sizes and routes. Hull design involves choosing proper proportions, decreasing resistance and evaluating the impact on resistance of sea waves and strong wind. Also, it is important to focus ship voyage planning and propeller cleaning to ensure necessary improvement trough ship energy efficiency.

IV. CONCLUSIONS

Ship energy efficiency is one of the core operational issues for shipowner and operators as it establishes a tool to improve the energy efficiency of ship in a cost-effective manner. Since a large amount of energy is consumed by ships, safety practitioners have been seeking an alternative solution to improve energy efficiency and minimize environmental pollution. This paper attempts to provide an analytic approach to evaluate ship energy efficiency by analysing critical performance indicators such as voyage planning, hull design, speed optimisation, hull coating, etc. A fuzzy –AHP method is employed to achieve this purpose.

In the view of sensitive analysis, hull design of the ship (CPI) become prominent as the most critical indicators in terms of ship energy efficiency since there is significant boom in the extent of ship’s hull form and propeller design. The outcomes of this paper are to encourage shipowner and operator focusing on options such as hull form optimisation and maintenance being prompted to enhance ship efficiency. The further study may be extended somehow to deal with resistance which is the major component of high energy consumption at ships.

<table>
<thead>
<tr>
<th>Table IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuzzy value</strong></td>
</tr>
<tr>
<td>CPI₁ (0.146, 0.243, 0.389)</td>
</tr>
<tr>
<td>CPI₂ (0.052, 0.089, 0.152)</td>
</tr>
<tr>
<td>CPI₃ (0.078, 0.131, 0.224)</td>
</tr>
<tr>
<td>CPI₄ (0.024, 0.039, 0.070)</td>
</tr>
<tr>
<td>CPI₅ (0.071, 0.119, 0.206)</td>
</tr>
<tr>
<td>CPI₆ (0.025, 0.038, 0.062)</td>
</tr>
<tr>
<td>CPI₇ (0.035, 0.057, 0.097)</td>
</tr>
<tr>
<td>CPI₈ (0.019, 0.027, 0.045)</td>
</tr>
<tr>
<td>CPI₉ (0.158, 0.256, 0.403)</td>
</tr>
</tbody>
</table>

REFERENCES

Review of the Bismuth Telluride (Bi$_2$Te$_3$) Nanoparticle: Growth and Characterization

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Abstract— In this paper, a review of Bismuth Telluride (Bi$_2$Te$_3$) nanoparticle growth and its characterization at nanoscale are discussed through a theoretical and analytical process. Nanotechnology research has become challenging task for modern science and technology. Material of Bi$_2$Te$_3$ is basically known for thermoelectric generation. Now in nanotechnology, all devices are migrating to the level of nanometer scale, the significant amount of experiments are being progressed to keep it up with the rapidly growing research field of nanotechnology. For these reasons, the characterization of Bi$_2$Te$_3$ at nanoscale is investigated and its application as a thermoelectric generator (TEG), thermoelectric cooling (TEC) and other field of material technology is presented. Finally, it is concluded that Bi$_2$Te$_3$ nanoparticles have many future aspect and applications.

Keywords — Bismuth Telluride (Bi$_2$Te$_3$); Nanotechnology; Nanoparticle; Thermoelectric Generator

I. INTRODUCTION

This review paper presents an overview of the remarkable research progress on Bismuth Telluride (Bi$_2$Te$_3$) nanoparticle growth by solvothermal process. Bi$_2$Te$_3$ basically is a compound element of Bismuth (Bi) and Tellurium (Te). Bi physically behaves like a metal and when it is alloyed with Te then it behaves like an efficient thermoelectric type material which can be used for thermoelectric refrigeration, thermoelectric cooling (TEC) and other field of material science such as thermal sensor, thermoelectric generator (TEG) etc. [1-4].

Bi$_2$Te$_3$ and its alloys are most important semiconductor thermoelectric materials that used in state-of-the-art devices which temperature range between 200 and 400 K. The figure of merit, $ZT = (\alpha^2 \sigma / \kappa) T$, of the best Bi$_2$Te$_3$ based alloys is about unit [5], where $\alpha$ is the Seebeck coefficient, $\sigma$ and $\kappa$ the electric and thermal conductivity, respectively.

Many works have been done in recent years to improve the thermoelectric properties of Bi$_2$Te$_3$ based alloys. It was reported that the figure of merit of thermoelectric materials could be significantly improved if the materials were nanostructured [6]. In the present work, we discussed the review of the Bi$_2$Te$_3$ nanoparticle has been growth by solvothermal process [6-15].

II. FORMATION OF BISMUTH TELLURIDE

There are two approaches for any nanostructure formation and fabrication. First is the top-down and second is the bottom-up approach [16]. The top-down approach includes the successive splitting of the bulk to nanostructure materials. However, in the bottom-up approach, the process to construct nanoparticles is started from building up from the atomic or molecular scale to until the nanoparticle is constructed.

Nowadays, although the top-down approach has been becoming out-dated rapidly, the bottom-up approach has been becoming appreciable in industrial applications over a decade. The bottom-up approach produces significantly best option of realizing nanostructures with very low record of defects in it and also provides more homogeneous chemical compositions.

Analysis on the characterization and growth of Bi$_2$Te$_3$ has already utilized both the top-down and the bottom-up approaches in the last three decades. In the growth process, these methods are generally categorized into two methods, first the physical and second the chemical methods. In the growth of Bi$_2$Te$_3$, the physical methods basically involve evaporation, sputtering and spray pyrolysis techniques. In the chemical methods which involve electrochemical, chemical vapour, laser chemical vapour and electrolysis deposition, hydrothermal and solvothermal processes. The solvothermal process is the most common technique among the chemical methods.

III. LITERATURE REVIEW

Thermoelectric materials have attracted a great interest owing to their potential applications in TEGs, TECs and other field of material science.

A thermoelectric device is an energy conversion system that converts thermal energy to electrical energy. TEC occurs when the couple is put in a thermal gradient (i.e., the top is hotter than the bottom), in which case the device generates a current, thereby converting heat into electrical power by a phenomenon referred to as the Seebeck effect. Conversely, TEC occurs when current passes through the thermocouple, in which case the thermocouple cools on one side and heats on the other side by a phenomenon known as the Peltier effect.

Bi$_2$Te$_3$ is one of the best thermoelectric materials because they have the capability to convert waste heat energy into useful electric energy. In order to develop the solvothermal method, Bi$_2$Te$_3$ can be used to fabricate nanostructured form.

Recently, researchers have attempted to improve the efficiency of Bi$_2$Te$_3$ materials by creating the nanostructures where one or more dimensions are reduced, such as nanorod, nanowires, nanoplates, nanotubes, nanoflowers and nanosheets etc. [6, 8, 17-19]. The solvothermal method is found to be a simple way of preparing nanomaterials. In the preparation process, the size of crystal grain, formation of
phase and growth of morphology can be well controlled. This method does not need organometallic precursors. In this section, solvothermal methods with reference to Bi$_2$Te$_3$ nanoparticles are reviewed.

Yuan Deng et al. [15] reported a solvothermal reaction of Bismuth (III) chloride dihydrate BiCl$_3$·2H$_2$O, Tellurium powder Te, Potassium hydroxide KOH, Potassium borohydride KBH$_4$ with the solvent of N, N-dimethyl formamide (DMF) at temperature between 100 and 180°C to produce nanocrystalline Bi$_2$Te$_3$. They proposed the formation mechanism of Bi$_2$Te$_3$ nanoparticles could be a combination of two independent pathways. The first pathway, Te was reduced to Te$^{2-}$ and then Te$^{2-}$ reacts with Bi$^{3+}$. The second pathway was a direct combination of metal; Bismuth ions (Bi$^{3+}$) could be reduced to metal Bismuth readily by KBH$_4$ to form Bi$_2$Te$_3$ nanoparticles. The X-ray diffraction (XRD) pattern of the product revealed that the peaks in the patterns corresponded to the reflections of rhombohedral phase with cell constants a = 4.38 Å and c = 30.50 Å. Morphology and size of synthesized nanoparticles were depended on the reaction temperature and time. When reaction temperature was low and also time was short, the first pathway was the dominant formation process; and it was easy to form rod-like nanoparticles. When the reaction temperature increased or the time was prolonged, the second pathway could be occurred; the morphology of Bi$_2$Te$_3$ nanocrystals tends to be sphere shaped.

X.B. Zhao et al. [14] were prepared by solvothermal synthesis to produce Bi$_2$Te$_3$ nanoparticles and nanowires by using Bismuth (III) chloride BiCl$_3$ and Te as a precursor with ethylene diamine (EN), dimethyl formamide (DMF), pyridine, acetone, ethanol and distilled water respectively as the reaction medium. A sufficient amount of NaBH$_4$ was put into the solution as the reductant and NaOH used to control the pH-value of the solution. According to the XRD results, the major by-products were metallic Bi, Te and Bismoclite (BiOCl). This means that in addition to the expected reaction for Bi$^{3+}$ ions to combine with the reduced Te$^{2-}$ ions to form Bi$_2$Te$_3$ during solvothermal synthesis. Distilled water was the best solvent for the solvothermal synthesis of Bi$_2$Te$_3$. The product synthesized in distilled water contained a large portion of nanowires with a diameter less than 100 nm and length of about 10 μm.

Yongbin Xu et al. [13] reported about the solvothermal methods by using the material Bi$_2$Cl$_3$, Te, Sodium hydroxide NaOH, Sodium borohydride NaBH$_4$ and the solvent of hexadecyltri methyl ammonium bromide (CTAB) mixed with distilled water & ethanol. The experimental results showed that CTAB played a vital role to the formation of the plate-like morphology and controlled the growth rates of different crystalline faces. XRD pattern indicated a pure rhombohedral phase with lattice constants a = 4.435 Å and c = 30.056 Å and produced pure Bi$_2$Te$_3$. In other experimental results the authors demonstrated single crystalline nanoparticles of Bi$_2$Te$_3$ were produced with 70 to 200 nm diagonal and 30 nm thickness.

S. H. Kim et al. [12] produced a Bi$_2$Te$_3$ alloy nanotubes with 1–D structure by interfusion at the interface of Bi and Te. The author’s used the material Bismuth (III) oxide Bi$_2$O$_3$, Tellurium dioxide TeO$_2$ which dissolved in Hydrochloric acid HCl and employed as a solvent of Olic acid and Oleylamine at reaction temperature between 160 and 240°C in a nitrogen atmosphere. Moreover, the author’s synthesized the Te nanowire at a temperature of 200°C with an average diameter of 150 to 200 nm and length of 10 to 15 μm. The Te nanowire was developed into Bi$_2$Te$_3$ nanotubes conformed by TEM images. Additionally, they observed the Bi and Te crystals in the XRD patterns.

Y. Liang et al. [11] employed a simple solvothermal process by using Bi$_2$O$_3$, Te that were added to the polyvinylpyrrolodone (PVP) with ethylene glycol solution in order to prepare Bi$_2$Te$_3$ hexagonal nanoplates in the absence of NaOH. According to the author reports, the diffraction peaks in the XRD pattern could be indexed to Bi$_2$Te$_3$ rhombohedral lattice phase with the lattice constants a = 4.395 Å and c = 30.44 Å. Thus the XRD data indicated that Bi$_2$Te$_3$ nanoplates prepared this method was composed of Bi$_2$Te$_3$ rhombohedral lattice phase. Author’s showed the transmission electron microscope (TEM) image of a single hexagonal Bi$_2$Te$_3$ nanoplate used to make a detailed investigation of crystallinity and microstructure. Corresponding spot pattern of selected area diffraction (SAED) and high-resolution transmission electron microscope (HRTEM) lattice demonstrated the single crystalline nature of the nanoplate. The SAED pattern was obtained by aligning the electron beam perpendicular to the face of this plate. The hexagonally symmetric spot pattern indicated the single crystallinity and could be indexed based on a rhombohedral phase. An HRTEM image revealed the expected hexagonal lattice fringes with a lattice spacing of 0.223 nm, indicating that the as-prepared nanoplates were highly crystallized. The Raman spectrum showed that infrared (IR) active mode, which must be odd parity and is Raman forbidden for bulk crystal due to its inversion symmetry, was greatly activated and shown up clearly in Raman scattering spectrum.

H. He et al. [10] were prepared the Bi$_2$Te$_3$ nanosheets by the solvothermal method. The raw materials were Bi$_2$O$_3$, TeO$_2$, glycol, NaOH and PVPK-30. The samples were a hexagonal lattice with an average crystal size of 42 nm. Scanning electron microscope (SEM) revealed the samples excellent hexagonal nanosheets, which was in accordance with the results obtained by XRD. The diameter and thickness of the nanosheets could be estimated to be 400 to 600 and 40 to 50 nm, respectively.

On the other hand, the authors report indicated that the absorption spectrum which exist two absorption peaks around 362 nm (with energy of 3.43 eV) and 663 nm (with energy of 1.87 eV). The electron affinity of Te was 1.97 eV. Taking the chemically combined Te atoms in Bi$_2$Te$_3$ nanosheets into consideration, the value of the electron affinity might be changed. The absorption peak around 663 nm corresponds to the electron affinity of Te. In order to confirm the conclusion, the emission spectrum of the Bi$_2$Te$_3$ nanosheets was obtained. The theoretical value of the electron affinity (1.97 eV) was slightly different from the experimental value (1.87 eV).
Y. Zhang et al. [9] reported the hexagonal nanosheet of Bi$_2$Te$_3$ single crystals with uniform morphology through a high yield solvothermal route at low temperature. The author’s used the raw materials such as BiCl$_3$, Sodium telluride Na$_2$TeO$_3$, NaOH, and the kind of surfactants that PVP-K30, ethylen diamine tetra acetic acid (EDTA), CTAB, sodium dodecyl benzene sulfonates (SDBS), ethylene glycol (EG). The author’s obtained the nanosheets by solvothermal route display a pure rhombohedral phase of Bi$_2$Te$_3$. The calculated lattice constants were $a = 4.386$ Å and $c = 30.482$ Å. The experimental results clearly explained that high-yield hexagon nanosheets were obtained, which have a thickness of 40 to 60 nm and a distance of 400 to 600 nm between the opposite edges. These nanosheets exhibited a flat surface and sharp edges, which indicated an excellent crystallinity. Reaction time and temperature, concentration of NaOH, and kinds of surfactants played important roles in the growth of Bi$_2$Te$_3$ nanocrystals.

R. Jin et al. [8] synthesized a hierarchical flower-like Bi$_2$Te$_3$ through a facile solvothermal method. Author’s employed the Bismuth (III) nitrate pentahydrate Bi(NO$_3$)$_3$·5H$_2$O and Na$_2$TeO$_3$ which dissolved in the water and EG solution. Glucose, NaOH and hydrate hydrate N$_2$H$_4$·H$_2$O were added into the solution. The XRD pattern of the obtained products demonstrated a rhombohedral phase of Bi$_2$Te$_3$. No other crystalline impurities were detected, indicating the phase purity of the Bi$_2$Te$_3$ product. The SEM images displayed that the Bi$_2$Te$_3$ had a flower-like morphology with the width of 300 to 2000 nm. Closer observation demonstrated that the flowers were composed of smaller nanospheres with the average thickness of 30 nm. The concentration of glucose played a crucial role in the formation mechanism on structure and morphology. The results showed that the maximum ZT value of 0.6 could be achieved at 600 K.

Lei Yang et al. [7] inspected an N-type Bi$_2$Te$_3$ nanostructure by using a solvothermal method and enhanced thermoelectric performance. They were used the Bi$_2$O$_3$, TeO$_2$, NaOH, EG and PVP in order to produce the Bi$_2$Te$_3$ nanostructures. Author’s indexed exclusively the XRD as a rhombohedral phase with lattice parameters were $a = 4.386$ Å and $c = 30.478$ Å. The SEM images displayed that the Bi$_2$Te$_3$ had a hexagonal plate-like nanostructures. The lateral size distributions of these nanostructures were varied from 100 to several 100 of nanometres. Their typical thickness could be observed in the high magnification SEM, which was around 20 nm. These structural features reduced the overall thermal conductivity and in turn led to an enhanced ZT of 0.88 at 400 K.

W. Guo et al. [6] prepared the hierarchical Bi$_2$Te$_3$ nanoflowers assembled by 2-D thin nanosheets with defects by using a facile solvothermal method. They used the materials of Bi(NO$_3$)$_3$·5H$_2$O, Na$_2$TeO$_3$, PVP K30, EG, hydrazine monohydrate N$_2$H$_4$, formic acid, ethanol and acetone. The peaks in the XRD pattern were well indexed to the rhombohedral Bi$_2$Te$_3$. The low-magnification FE-SEM image shows that Bi$_2$Te$_3$ sample was composed of hierarchical nanoflowers assembled by curved and inter crossed nanosheets. The high magnification FE-SEM image further showed that of Bi$_2$Te$_3$ nanosheets had a diameter ranging from 500 to 600 nm and a thickness of about 16 nm. Authors were achieved the controllable self-assembly of nanoflowers consisted of 2-D thin nanosheets. The results showed that the maximum ZT value of 0.68 at 475 K.

The Bi$_2$Te$_3$ nanostructures have unique properties, which is summarized in the Table I. Table II shows the growth and characterization parameters of Bi$_2$Te$_3$ nanostructure:

<table>
<thead>
<tr>
<th>Table I</th>
<th>PROPERTIES OF BISMUTH TELLURIDE NANOSTRUCTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Properties</td>
</tr>
<tr>
<td>ZT Value</td>
<td>0.60 to 0.88</td>
</tr>
<tr>
<td>Crystal Structure</td>
<td>Hexagonal-Rhombohedral Phase</td>
</tr>
<tr>
<td>Lattice Constant</td>
<td>$a = 4.336$ Å and $c = 30.439$ Å</td>
</tr>
<tr>
<td>Crystalline Size</td>
<td>42 nm</td>
</tr>
<tr>
<td>Width</td>
<td>300 to 2000 nm</td>
</tr>
<tr>
<td>Diameter</td>
<td>400 to 600 nm</td>
</tr>
<tr>
<td>Thickness</td>
<td>16 to 60 nm</td>
</tr>
<tr>
<td>Electron Affinity</td>
<td>3.7 to 4.2 eV</td>
</tr>
<tr>
<td>Band Gap</td>
<td>$\sim 0.15$ eV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table II</th>
<th>GROWTH AND CHARACTERIZATION PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth</td>
<td>Main Chemicals</td>
</tr>
<tr>
<td>Nanoflower</td>
<td>Bi(NO$_3$)$_3$·5H$_2$O, Na$_2$TeO$_3$</td>
</tr>
<tr>
<td>Nanostructure</td>
<td>Bi$_2$O$_3$, TeO$_2$</td>
</tr>
<tr>
<td>Nanoflower</td>
<td>Bi(NO$_3$)$_3$·5H$_2$O, Na$_2$TeO$_3$</td>
</tr>
<tr>
<td>Nanosheet</td>
<td>BiCl$_3$, Na$_2$TeO$_3$</td>
</tr>
<tr>
<td>Nanosheet</td>
<td>Bi$_2$O$_3$, TeO$_2$</td>
</tr>
<tr>
<td>Nanoplate</td>
<td>Bi$_2$O$_3$, Te</td>
</tr>
<tr>
<td>Nanotube</td>
<td>Bi$_2$O$_3$, TeO$_2$</td>
</tr>
<tr>
<td>Nanoplate</td>
<td>BiCl$_3$, Te</td>
</tr>
<tr>
<td>Nanowire</td>
<td>BiCl$_3$, Te</td>
</tr>
<tr>
<td>Nanorod</td>
<td>BiCl$_3$, Te</td>
</tr>
</tbody>
</table>

Bi$_2$Te$_3$ is one of the best thermoelectric materials with a relatively high electrical conductivity and lower thermal conductivity. Already a lot of works has been done in Bi$_2$Te$_3$. Recent advances in theories and experiments have proved that defects can break the sub lattice symmetry and are thought to play a key role in the electronic scattering processes in the nanosheets. Thus, to enhance the transport and electronic properties of Bi$_2$Te$_3$ crystals, the ability to manipulate hierarchical Bi$_2$Te$_3$ nanostructures with defects is highly
desirable. In this communication, the controllable Bi$_2$Te$_3$ single crystal nanostructure to improve the thermoelectric performance, which governed by the dimensionless figure-of-merit ZT.

IV. CONCLUSION AND FUTURE RESEARCH

Eventually, the use of main materials of Bi(NO$_3$)$_3$·5H$_2$O and TeO$_2$ in solvothermal growth has been proposed in the review paper. Since it’s are ecological behaviour with low toxicity, low cost, stability in air, commercial availability and easy of handling properties. Many researchers use the KOH and other materials to prepare the solution. Here, in order to prepare the solution, Nitric Acid HNO$_3$ instead of these materials has also been recommended. TeO$_2$ powder has been dissolved in HNO$_3$. Thereafter Bi(NO$_3$)$_3$·5H$_2$O material is added at 80°C and dissolved accompanied by magnetic stirring and complete the other treatments to produce Bi$_2$Te$_3$ nanostructure. Possible chemical reaction under as follows:

\[
\text{TeO}_2 + 2\text{HNO}_3 \rightarrow \text{H}_2\text{TeO}_4 + \text{NO}_2
\]

\[
\text{Bi(NO}_3)_3\cdot5\text{H}_2\text{O} \rightarrow \text{BiONO}_3 + 2\text{HNO}_3 + 4\text{H}_2\text{O}
\]

\[
3\text{HTeO}_4^- + 9\text{H}^+ + 18\text{e}^- \rightarrow \text{Bi}_2\text{Te}_3^- + 6\text{H}_2\text{O}
\]

Further research is required to improve the Seebeck coefficient while still keeping the thermal conductivity low and electrical conductivity high.

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REFERENCES

DETERMINATION OF WIND ENERGY POTENTIAL OF CAMPUS AREA OF SIIRT UNIVERSITY

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Abstract- In this study, wind energy potential of Siirt University campus area is statistically examined by using the mean hourly wind speed data between 2014 and 2015 years which are measured by Vantage Pro2 device, located at the roof of the Engineering Faculty building with 6 m altitude. Weibull distribution function and Rayleigh distribution function are used as statistical approach to evaluate the wind data. Weibull distribution function is examined by using two different methods that are maximum likelihood estimation and Rayleigh method. The determination coefficient ($R^2$) and Root Mean Square Error (RMSE) values of these methods are compared. According the error analysis, it is indicated that the Rayleigh method gives better results. Wind speed and wind power density are calculated in pursuance of Weibull distribution parameters. The results are evaluated as monthly and annually. Hence, this preliminary study is made to determine the wind energy potential of Siirt University campus area.

Keywords-Weibull distribution, Rayleigh distribution, maximum likelihood estimation, wind speed, wind power density.

I. INTRODUCTION

Electrical energy requirement tends to increase depending on the rapidly advancing technology. Due to the limited amount of available fossil fuels used in electricity production and due to the fact that they will eventually run out, the ways to conserve electric energy and the use of renewable energy sources are constantly being studied on. One of those studies is harvesting wind energy to generate electric energy which has shown great development in recent years, especially in Europe. Turkey is a country with high potential regarding wind energy. In 2007, Wind Energy Potential Map of Turkey (REPA) was published [1]. In this map, wind energy potential of Turkey was provided in detail for each city. In scope of this study, wind energy potential of Siirt campus area was studied and evaluated using the Vantage Pro2 device located at the roof of Block C of Engineering and Architecture Faculty, measuring the average hourly wind speeds between years 2014 and 2015 for a total of 12 months from 6 meters of altitude. For the evaluation of wind data, Weibull and Rayleigh distribution functions were used as statistical approaches. These two distribution functions are widely used to determine the wind energy potential in many studies either in Turkey and other countries [2]. It is a known fact that wind data usually matches with Weibull distribution [2-4]. However, in some areas, wind data does not match with the two parameter Weibull distribution. But mostly, Weibull distribution is the method which is used to represent the wind distribution in many regions throughout the world. The reason for its use is because it fits perfectly with the wind distribution and also has a flexible distribution structure, also, its parameters can easily be determined and very few parameters are required. Its parameters can also easily be estimated for different altitudes, once one altitude parameters is determined [2].

Wind measurements are usually performed in the range of 10-30 meters, however, today's large and powerful wind turbines' hub height is much higher than this level. Thus, in order to deduct the value of wind speed in any particular altitude, for any spot which was measured for just one altitude, wind power profile law is being used. Weibull distribution function parameters have been analyzed using two different methods which are maximum likelihood estimation (MLE) and Rayleigh method. Both methods have been compared with coefficient of determination ($R^2$) and root mean square error (RMSE) analysis. Average speed and wind power density have been statistically determined depending on the Weibull distribution parameters.

II. WEIBULL DISTRIBUTION

Weibull distribution is used to calculate wind energy potential in many studies. Wind data is known to usually fit to this type of distribution. However, in some areas, wind data does not conform to the two-parameter Weibull distribution. Various methods have been developed in order to calculate the figure (k) and scale (c) parameters. The methods that we used for Siirt campus area are the maximum likelihood estimation (MLE) and Rayleigh method. Likelihood density function of two parameter Weibull distribution is expressed with eq.(1).

$$f(v) = \frac{k}{c} \left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^k}$$  \hspace{1cm} (1)

Where the wind speed (m/s), k and c are dimensionless figure and scale parameters, respectively. The accumulation of Weibull
distribution (cumulative) likelihood density function is as in eq.(2) [5].

\[ F(v) = 1 - e^{-\frac{v}{c}} \]  

(2)

Weibull cumulative likelihood density function gives us the likelihood of the wind speed being actualized either smaller or equal to a specific v value. The average wind speed is calculated using the eq.(3) [5].

\[ V_{ort} = c \left( \frac{1}{k} + 1 \right) \]  

(3)

Weibull distribution is a function and this function has a peak spot. Finding this peak means finding the most probable speed, thus, finding the maximum wind speed. It is the (y) gamma function in eq.3 [2].

\[ V_{enolax} = c \left( \frac{k}{k} - 1 \right)^{\frac{1}{k}} \]  

(4)

The speed value which contributes the most to the energy flow is given in eq.(5) [2]

\[ V_{max} = c \left( \frac{k + 2}{k} \right)^{\frac{1}{k}} \]  

(5)

The average power density was shown in eq.(6) [3].

\[ P = \frac{1}{2} \rho c^3 \gamma (1 + \frac{3}{k}) \]  

(6)

Where, "\( \rho \)" is the air density value and in calculations it was taken as an average of 1.226 kg/m³ for Siirt campus area. Figure parameter (k) is a parameter indicating the frequency of the wind. If the wind speed does not show much fluctuation in an area, and if the wind is blowing with an approximate constant speed (low or high), it k parameter is greater. Scale parameter (c) indicates the relative cumulative wind speed frequency. In simple words, c parameter changes depending on the average speed. If the average speed is higher, c parameter is also higher [3]. Wind speed measurements are usually made in between an altitude range of 10 to 30 meters. However, nowadays, the hubs of wind turbines are much higher than this level. Therefore, in order to deduct the wind speed value of any particular altitude of any location, wind power profile law is being used together with the measured wind speed data of that location [6]. Speed values for different altitude are measured using eq.(7).

\[ \left( \frac{V_2}{V_1} \right) = \left( \frac{h_2}{h_1} \right) \]  

(7)

In eq.(7), \( V_1 \) represents the measured wind speed, \( V_2 \) represents the desired wind speed, \( h_1 \) represents the altitude that the \( V_1 \) speed was measured, \( h_2 \) represents the altitude that \( V_2 \) speed is demanded to be determined, \( \alpha \) represents the Hellman coefficient and is dependent on the specifications of the location of the wind speed measurement is made.

\[ \left( \frac{P_2}{P_1} \right) = \left( \frac{h_2}{h_1} \right)^{3\alpha} \]  

(8)

If the power level in the reference altitude can be found using eq.(8), the power density in the desired altitude can be calculated also. In the equation, \( h_1 \) is the reference altitude, and if the power density in this altitude is \( P_1 \) and the power density in the desired altitude (\( h_2 \)) is represented with \( P_2 \).

III. MAXIMUM LIKELIHOOD ESTIMATION

Maximum likelihood estimation is one of the methods to find the k and c values which are the figure and scale parameters of Weibull distribution. In maximum likelihood estimation, wind data shall be organized as \( V_1, V_2, V_3, \ldots, \ldots, V_n \) which will form a set with \( n \) number of elements. The likelihood of any data to be \( V=V_i \) is proportional with \( f(V; k, c) \). Similarly, the likelihood of \( V=V_1, \ldots, V=V_n \) occurrence of all the data can also be expressed. These events are independent from each other. Thus, the likelihood of the occurring of events can be defined as a likelihood function as in eq.(9) [7].

\[ L = \prod_{i=1}^{n} f(V_i; k, c) \]  

(9)

The scale parameter can be obtained using eq.(10).

\[ c = \left( \frac{\sum_{i=1}^{n} V_i^k}{n} \right)^{\frac{1}{k}} \]  

(10)

Figure parameter can be calculated using eq.(11).

\[ k = \left( \frac{\sum_{i=1}^{n} V_i^k \ln(V_i)}{\sum_{i=1}^{n} (V_i)^k} - \frac{\sum_{i=1}^{n} \ln(V_i)}{n} \right)^{-1} \]  

(11)

The likelihood function can be used to find the value that will make the highest likelihood function, for the k and c parameters calculated using above given equations. Here, the equation for \( V_i=0 \) which is used for k figure parameter can not be solved. Therefore, the value of 0 should be removed from the dataset [2].
IV. RAYLEIGH DISTRIBUTION

The change and distribution of the wind in a specific period is very important for energy production evaluations. Turbine designers need such information like wind distribution and change in order to make improvements on turbines and to reduce the costs to a minimum. If in any location, the only known data is the average wind speed \( \langle V \rangle \); using Rayleigh distribution function, it should be possible to find the percentage of any specific wind speed \( V \) blowing time (hr). The wind speed values derived from such calculations are a distribution of likelihood density. When this distribution is schematically depicted, the region which is below this distribution is equal to 1. Because the likelihood of the wind blowing in any speed including zero is equal to 100%. Rayleigh density function is as it was shown in eq.(12) [2, 5-10].

\[
f_r(\nu) = \left( \frac{\nu}{\nu_m} \right) \exp \left[ -\left( \frac{\nu}{\nu_m} \right)^2 \right] \quad (12)
\]

Rayleigh cumulative distribution function can be represented as in eq.(13)

\[
F_r(\nu) = 1 - \exp \left[ -\left( \frac{\nu}{\nu_m} \right)^2 \right] \quad (13)
\]

The biggest advantage of Rayleigh distribution is that the distribution can be determined with just using the average wind speed. In Rayleigh distribution, calculations are done considering that the \( k \) scale parameter equals to 2. Because the calculations are made over a single parameter, it is a simpler method compared to Weibull distribution. Its validity in wind studies have been shown in many references [2-5].

V. ERROR ANALYSIS

Error analysis shall be done in order to find out which of the figure and scale parameters calculated using Weibull distribution, MLE and Rayleigh are the most suitable ones for the real data. The methods used in this study have been analyzed using two different error analysis methods. The first of these is \( R^2 \) (determining coefficient) and it can be expressed as in eq.(14) [2, 8, 9].

\[
R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - x_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (14)
\]

The other error analysis method is root mean square error (RMSE), and it has been represented in eq.(15).

\[
RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n}(y_i - x_i)^2} \quad (15)
\]

Where, \( n \) is the number of observations, \( y \) are real values, \( x \) are values calculated using Weibull distribution and average real values. The fact that \( R^2 \) value is the largest and RMSE value is the smallest shows that this distribution function is the best one [2, 8, 9].

VI. RESULTS AND DISCUSSION

In the estimation of the parameters of Weibull distribution and Rayleigh function, hourly wind speed data measured in 6 meters of altitude for 12 months between 2014 and 2015 in Siirt campus area was used. Then the results for 40 meters of altitude were calculated using Hellmann coefficient.

Table 1. Weibull parameter, speed and power estimates for 2014-2015 data of Siirt campus area

<table>
<thead>
<tr>
<th></th>
<th>k</th>
<th>c</th>
<th>( \langle \nu \rangle ) (m/s)</th>
<th>( \sigma ) (m/s)</th>
<th>( f_r(\nu) )</th>
<th>( F_r(\nu) )</th>
<th>( V_{mean} ) (m/s)</th>
<th>( V_{max} ) (m/s)</th>
<th>P/A (w/m²) 6m</th>
<th>P/A (w/m²) 40m</th>
</tr>
</thead>
<tbody>
<tr>
<td>JULY-2014</td>
<td>1.2269</td>
<td>1.9318</td>
<td>1.8002</td>
<td>1.4808</td>
<td>0.6020</td>
<td>0.2489</td>
<td>0.4882</td>
<td>4.2488</td>
<td>3.6179</td>
<td>8.9892</td>
</tr>
<tr>
<td>AUGUST</td>
<td>1.1412</td>
<td>1.6777</td>
<td>1.6003</td>
<td>1.4055</td>
<td>0.2620</td>
<td>0.6123</td>
<td>0.2689</td>
<td>4.0741</td>
<td>2.5122</td>
<td>6.2419</td>
</tr>
<tr>
<td>SEPTEMBER</td>
<td>1.2241</td>
<td>1.7396</td>
<td>1.6282</td>
<td>1.3371</td>
<td>0.2757</td>
<td>0.6024</td>
<td>0.4345</td>
<td>3.8375</td>
<td>2.6460</td>
<td>6.5744</td>
</tr>
<tr>
<td>OCTOBER</td>
<td>1.3019</td>
<td>1.2766</td>
<td>1.7877</td>
<td>0.9131</td>
<td>0.4042</td>
<td>0.5940</td>
<td>0.4154</td>
<td>2.6094</td>
<td>1.0039</td>
<td>2.4943</td>
</tr>
<tr>
<td>NOVEMBER</td>
<td>1.1994</td>
<td>1.1068</td>
<td>1.0413</td>
<td>0.8718</td>
<td>0.4227</td>
<td>0.6052</td>
<td>0.2480</td>
<td>2.5080</td>
<td>0.6920</td>
<td>1.7193</td>
</tr>
<tr>
<td>DECEMBER</td>
<td>1.7899</td>
<td>0.7339</td>
<td>0.6528</td>
<td>0.3772</td>
<td>0.9882</td>
<td>0.5556</td>
<td>0.4647</td>
<td>1.1160</td>
<td>0.1705</td>
<td>0.4236</td>
</tr>
<tr>
<td>JANUARY 2015</td>
<td>1.1195</td>
<td>1.1532</td>
<td>1.1065</td>
<td>0.9901</td>
<td>0.3718</td>
<td>0.6151</td>
<td>0.1563</td>
<td>0.8305</td>
<td>0.8305</td>
<td>2.0685</td>
</tr>
<tr>
<td>FEBRUARY</td>
<td>1.1919</td>
<td>1.4217</td>
<td>1.3397</td>
<td>1.1285</td>
<td>0.3265</td>
<td>0.6061</td>
<td>0.3071</td>
<td>3.2491</td>
<td>1.4740</td>
<td>3.6623</td>
</tr>
<tr>
<td>MARCH</td>
<td>1.1853</td>
<td>1.5221</td>
<td>1.4364</td>
<td>1.2164</td>
<td>0.3029</td>
<td>0.6069</td>
<td>0.3180</td>
<td>3.5047</td>
<td>1.8168</td>
<td>4.5141</td>
</tr>
<tr>
<td>APRIL</td>
<td>1.1440</td>
<td>1.9039</td>
<td>1.8147</td>
<td>1.5902</td>
<td>0.2316</td>
<td>0.6119</td>
<td>0.3110</td>
<td>4.6074</td>
<td>3.6636</td>
<td>9.1065</td>
</tr>
<tr>
<td>MAY</td>
<td>1.3280</td>
<td>2.0167</td>
<td>1.8548</td>
<td>1.4103</td>
<td>0.2618</td>
<td>0.5913</td>
<td>0.7036</td>
<td>0.5913</td>
<td>3.9118</td>
<td>9.7195</td>
</tr>
<tr>
<td>JUNE</td>
<td>1.3406</td>
<td>2.4522</td>
<td>2.2515</td>
<td>1.6968</td>
<td>0.2177</td>
<td>0.5901</td>
<td>0.8823</td>
<td>4.8456</td>
<td>6.9960</td>
<td>17.3827</td>
</tr>
</tbody>
</table>

Table 1 shows the analysis of hourly wind data in Siirt campus. Calculations were performed with hourly measurements made at an altitude of 6 meters. Then, using Helmann coefficient, wind power density was calculated for the altitude of 40 meters. As seen in table 1, the highest average
speed and power density in Siirt Campus took place in June. But these two data distributions are not sufficient for energy investments, it is necessary to examine the distributions of other data as well. When we examine the seasonal data, we can see that the highest average speed and power density happens to be in summer and late spring months. Fig.1 shows the power density values calculated in the years 2014-2015 for Siirt Campus area.

![Power density graph](image)

Fig.1. Power densities calculated using MLE for years in between 2014-2015

Depending on the altitude, wind speed and its power density varies. Parameter values in different altitudes were deducted from the revised data obtained for the altitude of 6 meters and by adapting it to 40 meters of altitude.

Table 2. Rayleigh parameter, speed and power estimates for 2014-2015 data of Siirt campus area

<table>
<thead>
<tr>
<th></th>
<th>c</th>
<th>$V_0$ (m/s)</th>
<th>$\sigma$ (m/s)</th>
<th>$f_r$ (ν)</th>
<th>$F_r$ (ν)</th>
<th>$V_{mostlik}$ (m/s)</th>
<th>$V_{max}$ (w/m²) 6m</th>
<th>P/A (w/m²) 6m</th>
<th>P/A (w/m²) 40m</th>
</tr>
</thead>
<tbody>
<tr>
<td>JULY-2014</td>
<td>2.3422</td>
<td>2.0757</td>
<td>0.7900</td>
<td>0.1508</td>
<td>0.9356</td>
<td>1.6562</td>
<td>3.3124</td>
<td>10.4710</td>
<td>26.0162</td>
</tr>
<tr>
<td>AUGUST</td>
<td>2.1796</td>
<td>1.9316</td>
<td>0.7352</td>
<td>0.2027</td>
<td>0.9070</td>
<td>1.5412</td>
<td>3.0824</td>
<td>8.4378</td>
<td>20.9646</td>
</tr>
<tr>
<td>SEPTEMBER</td>
<td>2.1141</td>
<td>1.8735</td>
<td>0.7131</td>
<td>0.2263</td>
<td>0.8930</td>
<td>1.4949</td>
<td>2.9897</td>
<td>7.6993</td>
<td>19.1297</td>
</tr>
<tr>
<td>OCTOBER</td>
<td>1.5322</td>
<td>1.3578</td>
<td>0.5168</td>
<td>0.4738</td>
<td>0.6908</td>
<td>1.0834</td>
<td>2.1668</td>
<td>2.9309</td>
<td>7.2821</td>
</tr>
<tr>
<td>NOVEMBER</td>
<td>1.4548</td>
<td>1.2893</td>
<td>0.4907</td>
<td>0.5049</td>
<td>0.6529</td>
<td>1.0287</td>
<td>2.0374</td>
<td>2.5089</td>
<td>6.2336</td>
</tr>
<tr>
<td>DECEMBER</td>
<td>0.7592</td>
<td>0.6728</td>
<td>0.2561</td>
<td>0.5691</td>
<td>0.5369</td>
<td>1.0737</td>
<td>0.3566</td>
<td>0.8860</td>
<td>0.8860</td>
</tr>
<tr>
<td>JANUARY 2015</td>
<td>1.6483</td>
<td>1.4607</td>
<td>0.5560</td>
<td>0.4237</td>
<td>0.7429</td>
<td>1.1655</td>
<td>2.3310</td>
<td>3.6490</td>
<td>9.0663</td>
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<td>FEBRUARY</td>
<td>1.8286</td>
<td>1.6205</td>
<td>0.6168</td>
<td>0.3436</td>
<td>0.8121</td>
<td>1.2930</td>
<td>2.5860</td>
<td>4.9894</td>
<td>12.3967</td>
</tr>
<tr>
<td>MARCH</td>
<td>1.9776</td>
<td>1.7526</td>
<td>0.6671</td>
<td>0.2798</td>
<td>0.8585</td>
<td>1.3984</td>
<td>2.7968</td>
<td>6.3028</td>
<td>15.6599</td>
</tr>
<tr>
<td>APRIL</td>
<td>2.4870</td>
<td>2.2040</td>
<td>0.8389</td>
<td>0.1129</td>
<td>0.9546</td>
<td>1.7585</td>
<td>3.5171</td>
<td>12.5343</td>
<td>31.1627</td>
</tr>
<tr>
<td>MAY</td>
<td>2.3389</td>
<td>2.0728</td>
<td>0.7889</td>
<td>0.1517</td>
<td>0.9351</td>
<td>1.6539</td>
<td>3.3077</td>
<td>10.4264</td>
<td>25.9054</td>
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<tr>
<td>JUNE</td>
<td>2.7890</td>
<td>2.4717</td>
<td>0.9407</td>
<td>0.0571</td>
<td>0.9795</td>
<td>1.9721</td>
<td>3.9443</td>
<td>17.6790</td>
<td>43.9552</td>
</tr>
</tbody>
</table>

Table 2 shows the analysis according to Rayleigh distribution of the hourly wind speed data for Siirt campus area for years 2014-2015. According to the calculations, the highest power density was recorded in June and the lowest was recorded in December.
Fig. 2 shows the power density data calculated using Rayleigh distribution for Siirt campus area for years 2014-2015. As can be seen in the figure, the highest power density was recorded in June and the lowest was recorded in December. The coefficient of determination ($R^2$) is valued either 0 or 1, as the measurement of the power of estimation of any model. The closer the coefficient of determination to 1, the higher the power of estimation of the model used. The smaller the RMSE value gets, the better that particular distribution function becomes.

Table 3. The comparison of likelihood distributions calculated using Rayleigh and Weibull distributions

<table>
<thead>
<tr>
<th>MONTHS</th>
<th>METHOD</th>
<th>$R^2$</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>July-2014</td>
<td>Weibull</td>
<td>0.87348</td>
<td>0.02658</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.98975</td>
<td>0.02431</td>
</tr>
<tr>
<td>August</td>
<td>Weibull</td>
<td>0.90545</td>
<td>0.03017</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.97552</td>
<td>0.02986</td>
</tr>
<tr>
<td>September</td>
<td>Weibull</td>
<td>0.92778</td>
<td>0.02653</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.98993</td>
<td>0.01749</td>
</tr>
<tr>
<td>October</td>
<td>Weibull</td>
<td>0.99543</td>
<td>0.00994</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.98847</td>
<td>0.00106</td>
</tr>
<tr>
<td>November</td>
<td>Weibull</td>
<td>0.91022</td>
<td>0.02452</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.94961</td>
<td>0.02957</td>
</tr>
<tr>
<td>December</td>
<td>Weibull</td>
<td>0.91665</td>
<td>0.01065</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.90463</td>
<td>0.01893</td>
</tr>
<tr>
<td>January-2015</td>
<td>Weibull</td>
<td>0.90956</td>
<td>0.03654</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.90077</td>
<td>0.03012</td>
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<tr>
<td>February</td>
<td>Weibull</td>
<td>0.92849</td>
<td>0.02986</td>
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<tr>
<td></td>
<td>Rayleigh</td>
<td>0.91199</td>
<td>0.02901</td>
</tr>
<tr>
<td>March</td>
<td>Weibull</td>
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</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.99123</td>
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<tr>
<td>April</td>
<td>Weibull</td>
<td>0.95457</td>
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</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.98656</td>
<td>0.03210</td>
</tr>
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<td>Weibull</td>
<td>0.95465</td>
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<td></td>
<td>Rayleigh</td>
<td>0.99645</td>
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</tr>
<tr>
<td>June</td>
<td>Weibull</td>
<td>0.94712</td>
<td>0.03789</td>
</tr>
<tr>
<td></td>
<td>Rayleigh</td>
<td>0.99223</td>
<td>0.02875</td>
</tr>
</tbody>
</table>
The data obtained from Weibull and Rayleigh distributions for Siirt campus area for 2014-2015 was presented in Table 3. When the table is examined, it can be seen that a statistical comparison of Weibull and Rayleigh distributions was made according to $R^2$ and RMSE criteria. If these comparisons are examined, it can be seen that the use of Rayleigh distribution is more suitable for that particular region. This can also be seen in Fig. 3. If the figure is examined, it can be seen that the highest coefficient of determination was obtained using Rayleigh distribution.

Fig.3. The comparison of Weibull and Rayleigh distributions according to $R^2$ criteria for Siirt campus area in between years 2014 and 2015

VII. CONCLUSIONS

For the determination of the wind potential of any region for energy purposes, its wind speed distribution should be known first. Depending on the wind speed distribution data, wind power density is calculated and after the required economic and environmental analysis, it can be understood if the wind farming would be beneficial for that particular area or not. In this study, Weibull parameters used to determine the distribution of speed have been determined using two different distribution methods, maximum likelihood estimation (MLE) and Rayleigh distribution method. As a result of the error analysis made in Siirt campus region, and also considering the $R^2$ and RMSE factors, it was seen that Rayleigh distribution gave better results. The data was obtained for 6 meters of altitude by using the device Vantage Pro2 device, located at the roof of the Engineering Faculty building, and using the Hellmann coefficient, the possible wind data for the altitude of 40 meters was calculated. Generally speaking, when evaluated for its wind potential throughout 2014-2015, for a period of 12 months, it has been understood that late Spring and Summer months had the highest potential of power density, and the lowest power density was observed in months of Winter and Fall. For any location to be eligible to have a wind farm, its power density should be over 50 W/m². In our measurements, we have come to the conclusion that in order to have a wind farm in this location, the wind turbine rotors should be situated above 40 meters of altitude.

REFERENCES


Pd based catalysts for fuel cell applications

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Abstract—Palladium–metal (Cobalt, Zinc, Vannadium, Manganese) bimetallic nanocatalysts were synthesized by polyol method using ethylene glycol (EG) as the solvent and performed reduction by using NaBH4 at room temperature. Glassy carbon (GC) electrodes are modified with the Pd based catalysts. The electrocatalytic properties of the PdM/CNT are examined for methanol, ethanol and ethylene glycol oxidation with cyclic voltammetry (CV) and chronoamperometry (CA). The electrocatalytic activity of PdCo/CNT is four, eight and ten times higher in methanol (MeOH), ethanol (EtOH) and ethylene glycol (EG), respectively compared to other catalyst modified electrodes (PdZn/CNT, PdV/CNT and PdMn/CNT).

Keywords—Palladium based catalysts, methanol oxidation, ethanol oxidation, ethylene glycol oxidation, cyclic voltammetry, chronoamperometry.

I. INTRODUCTION

Direct Oxidation Fuel Cells (DOFCs) are attracting widespread interest over the past few years due to their low pollution for the environment, easy transportation and handling. The fuel cells that operate directly using liquid fuels have focused attention on the electrochemical oxidation of alcohols and other small organic molecules such as methanol, ethanol, propanol, ethylene glycol, etc [1]. Methanol is the most studied liquid fuel even its high toxicity and high flammability. However C2-fuels such as ethanol and ethylene glycol are alternative to methanol due to their electro-oxidation at low temperatures and high energy density. DOFCs are promising power sources for portable electronic devices and electric vehicles. However, there are some problems such as slow reaction kinetics, catalyst poisoning and fuel crossover. Therefore, the study on catalyst material and preparation method to increase the activity and stability of the catalysts is important. The major reason to decrease catalytic activity is that the catalyst is affected by chemisorbed carbonaceous intermediates. It is well known that Pt and Pt-based alloys are promising catalysts used in direct oxidation fuel cells, but Pt has some limitations such as its limited abundance, high cost and low CO tolerance. However, Pd is more abundant, less expensive and stable in alkaline solutions than Pt. Moreover, Pd has better CO tolerance comparing to Pt catalysts. These properties have led to consider Pd based nanomaterials as effective catalysts for direct liquid fuel cells [2]. A number of studies have been devoted to Pd-based catalysts for the electrooxidation of alcohols in alkaline medium [3]-[5].

In the present study, the catalytic activities of PdM (M: Co, Zn, V, Mn) catalysts for different liquid fuels (MeOH, EtOH and EG) have been compared. The electrocatalytic activities of the catalysts are characterized with electrochemical methods such as cyclic voltammetry (CV) and chronoamperometry (CA) methods.

II. EXPERIMENTAL

A. Preparation of Catalysts
Carbon nanotube supported PdM catalysts were prepared by polyol method in ethylene glycol. In brief, certain amount of aqueous metal salts (Cobalt, Zinc, Vannadium, Manganese) solution was prepared. Then, appropriate amount of ethylene glycol and carbon nanotube support were added into the solution prepared. The pH of the solution was fixed at 10 by the addition of KOH solution and carbon nanotube support was dispersed in this solution. Certain amount of NaBH4 was added to above solution and stirred at room temperature under stirring.

B. Electrochemical Measurements
All the electrochemical measurements were conducted using CH Instruments 6043d potentiostat. The electrochemical experiments were carried out in an N2-purged NaOH solution and a standard three-electrode electrochemical cell. A Pt foil electrode and an Ag/AgCl served as the counter and reference electrode, respectively. Prior to each experiment GC electrode surface was polished with slurry of 0.05 mm alumina powder until a mirror-like surface obtained. Then the electrode was washed thoroughly with acetone and distilled water.

All electrochemical measurements were carried out in 1 M KOH. The alcohol concentrations are 1 M. The alcohols examined in the present study were MeOH, EtOH and EG. The CV technique was carried out by scanning of the potential between -1.0 and 0.4 V with the scan rate of 50 mV s⁻¹. Chronoamperometry experiments were performed at -0.35 V, at room temperature. All potentials in this article have been reported versus normal hydrogen electrode (NHE).

III. RESULTS AND DISCUSSION
The electrochemical characterization of PdM/CNT electrocatalysts was evaluated by cyclic voltammetry in the 1.0 M KOH solution at 25 °C. The cyclic voltammograms were recorded at 50 mV s⁻¹. The cyclic voltammetric behaviors of PtM catalysts were compared with each other. and presented in Fig. 1. The hydrogen adsorption/desorption peaks (in the −0.1 and 0.8 V region) and palladium oxide reduction peak (at −0.05 V) was seen in the figure. Higher
current value of hydrogen adsorption desorption peaks were obtained for PdCo/CNT catalyst.

Cyclic voltammetry (CV) is the most important electrochemical technique for acquiring information about catalysts activity toward alcohol oxidation. The CV provides basic information on the kinetics and thermodynamics of the electro-oxidation reaction. Some of these informations are established in terms of the (a) onset potential ($E_{\text{onset}}$), (the more negative the value the easier the electrocatalysis); (b) peak potential separation ($E_p$), (the lower the value the more efficient the catalyst) [6]; (c) forward peak current ($I_f$) maximum current of catalyst and (d) the ratio of forward to reverse peak current ($I_f/I_r$), (the higher the value the more tolerant to poisoning the catalyst) [7]. The CV data as depicted in Table I clearly show that the PtCo/CNT is a better catalyst for alcohol oxidation reaction than the other synthesized Pd based catalysts. The onset potential at the PtCo/CNT is more negative, while the current is about four, eight and ten times higher in methanol (MeOH), ethanol (EtOH) and ethylene glycol (EG), respectively than the other Pd based catalysts.

### Table I

<table>
<thead>
<tr>
<th>Catalyst</th>
<th>Alcohol</th>
<th>$E_{\text{onset}}$ (V)</th>
<th>$E_p$ (V)</th>
<th>$I_f$ (mA)</th>
<th>$I_r/I_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>PdCo/CNT</td>
<td>MeOH</td>
<td>-0.55</td>
<td>-0.242</td>
<td>0.231</td>
<td>5.7</td>
</tr>
<tr>
<td>PdZn/CNT</td>
<td></td>
<td>-0.40</td>
<td>-0.24</td>
<td>0.071</td>
<td>3.5</td>
</tr>
<tr>
<td>PdMn/CNT</td>
<td></td>
<td>-0.30</td>
<td>-0.226</td>
<td>0.067</td>
<td>3.1</td>
</tr>
<tr>
<td>PdV/CNT</td>
<td></td>
<td>-0.50</td>
<td>-0.23</td>
<td>0.032</td>
<td>1.5</td>
</tr>
<tr>
<td>PdCo/CNT</td>
<td>EtOH</td>
<td>-0.52</td>
<td>-0.226</td>
<td>0.41</td>
<td>1.2</td>
</tr>
<tr>
<td>PdZn/CNT</td>
<td></td>
<td>-0.44</td>
<td>-0.248</td>
<td>0.061</td>
<td>0.7</td>
</tr>
<tr>
<td>PdMn/CNT</td>
<td></td>
<td>-0.445</td>
<td>-0.30</td>
<td>0.018</td>
<td>0.6</td>
</tr>
<tr>
<td>PdV/CNT</td>
<td></td>
<td>-0.44</td>
<td>-0.285</td>
<td>0.041</td>
<td>0.4</td>
</tr>
<tr>
<td>PdCo/CNT</td>
<td>EG</td>
<td>-0.51</td>
<td>-0.211</td>
<td>0.543</td>
<td>1.9</td>
</tr>
<tr>
<td>PdZn/CNT</td>
<td></td>
<td>-0.48</td>
<td>-0.23</td>
<td>0.065</td>
<td>1.4</td>
</tr>
<tr>
<td>PdMn/CNT</td>
<td></td>
<td>-0.40</td>
<td>-0.25</td>
<td>0.067</td>
<td>1.2</td>
</tr>
<tr>
<td>PdV/CNT</td>
<td></td>
<td>-0.45</td>
<td>-0.26</td>
<td>0.089</td>
<td>1.3</td>
</tr>
</tbody>
</table>

A good fuel cell catalyst should have high current at low overpotentials, and retain such current at long period of time. The stability of current generated by the electrocatalyst was tested by chronoamperometric experiments. Fig. 3 compares the chronoamperometric curves of PdCo/CNT, PdZn/CNT, PdV/CNT and PdMn/CNT in KOH solutions of the three alcohols (methanol, ethanol and ethylene glycol). The chronoamperometric curves exhibit fast decrease at the initial period due to the accumulation of intermediate species at the surface of catalysts. As it was obtained from the CV measurements, PdCo/CNT catalyst shows a higher initial current and a higher current at the longer time. This confirms that PdCo/CNT, catalyst has higher electrocatalytic activity, higher resistance to CO, and better long term stability compared to the other three catalysts.

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**Fig. 1** Cyclic voltammogram of GCE modified PdCo/CNT (---), PdZn/CNT (-----), PdMn/CNT (-----) and PdV/CNT (-----) in 1 M KOH at 50 mV s$^{-1}$.  
**Fig. 2** Cyclic voltammogram of GCE modified PdCo/CNT (---), PdZn/CNT (-----), PdMn/CNT (-----) and PdV/CNT (-----) in MeOH (a), EtOH (b) and EG (c), 1 M KOH at 50 mV s$^{-1}$.  
**Fig. 3** Comparative electrocatalytic properties of the catalysts towards alcohol oxidation reaction.
IV. CONCLUSIONS

PdM nanocatalysts have been successfully prepared by polyol method with NaBH₄ reduction. Electrochemical study of alcohol electrooxidation reaction on Pd based catalysts was investigated by different electrochemical techniques. Cyclic voltametric and chronoamperometric measurements demonstrate that PdCo/CNT catalyst has higher catalytic activity than the other Pd based electrocatalyst for alcohol electro-oxidation in alkaline solution. The synthesized PdCo/CNT catalyst promises great potential as a kind of novel anode electrocatalyst with high electrochemical activity for application in DOFCs.

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Fig. 3 Chronoamperometric curves of GCE modified PdCo/CNT (―), PdZn/CNT (・・・), PdMn/CNT (・・・) and PdV/CNT (―) in MeOH (a), EtOH (b) and EG (c) (1 M KOH/1 M Alcohol) at -0.35 V.
Experimental Investigation and Fuzzy Logic Modeling of Performance Hydroxy Dry Cell with Different Plate Combination  
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Abstract—In this study, hydroxy (HHO) dry cell with different plate combination performances in terms of current and temperature were experimentally investigated and modeled with Rule-Based Mamdani-Type Fuzzy (RBMTF) modeling technique. Input parameters plate number and time; output parameters current, temperature were described by RBMTF if-then rules. The dimensions of the plates were 9x9 cm², 10x10 cm² and 11x11 cm². Current and temperature were measured for the different plate combination. Tap water was used in the experiments and the system was set to 5 minutes. For each combination, new cells were prepared. Experimental data which obtained for current and temperature according to combination and time were used in the training step. Numerical parameters of input and output variables were fuzzificated as linguistic variables: very very low (L₁), very low (L₂), low (L₃), negative medium (L₄), medium (L₅), positive medium (L₆), high (L₇), very high (L₈) and very very high (L₉) linguistic classes. With the linguistic variables used, rules were obtained for this system. The comparison between experimental data and RBMTF is done by using statistical methods like the coefficient of multiple determinations (R²). The actual values and RBMTF results indicated that RBMTF can be successfully used in HHO dry cell.

Keywords—HHO Dry Cell, Plate Combination, Rule-based Mamdani-type fuzzy modelling

I. INTRODUCTION

Hydrocarbon fuel is one of the sources of energy used for electrical power generation, heating and transportation in the world. But they have negative side effects like polluting emissions, large scale oil spill, etc. Due to its widespread dependence and difficulties in getting other alternatives the use of hydrocarbon fuel could not be eliminated. To mitigate the above problems and to reduce the use of hydrocarbon fuel, hydrogen gas can be supplemented. Hydrogen gas to air intake of a combustion process will improve flame speed, lean burn ability and flame quenching distance. But scarcity and production cost makes it more difficult to implement. Hydrogen rich gas produced from electrolysis of water called the Brown’s Gas or Oxyhydrogen (HHO) could solve the potential difficulties [1].

In 1918 Charles Frazer, a North American inventor, patented the first water electrolysis machine act as a hydrogen booster for internal combustion engines. Yull Brown, a Bulgarian born Australian inventor patented and attempted to popularize Browns Gas as a cutting gas and fuel additive during the 1970’s and 80’s [2]. HHO is an enriched mixture of hydrogen and oxygen bonded together molecularly and magnetically. HHO Gas is produced in a common-ducted electrolyser & then sent to the intake manifold to introduce into combustion chamber of the engine. HHO gases will combust in the combustion chamber when brought to its auto-ignition or self-ignition temperature [3]. This Energy’s performance must be increased which is predicted to be more important in the future. One of the methods to determine the effects of the parameters on performance is fuzzy logic method.

In the existing literature, there have been many investigations on application of fuzzy logic. Some of briefly mentioned below. İşıktaş et al. [4] studied about fuzzy logic modelling of performance HHO dry cell with different type membership functions. They noted that RBMTF which has a triangular membership function has a more better performance than other membership functions for determine performance of HHO dry cell. Ata and Dincer [5-9] studied about rule-based Mamdani-type fuzzy (RBMTF) modelling of performance proton exchange membrane fuel cell with carbon nanotube. They noted that RBMTF can be successfully used for the specification PEM performances with coating carbon nanotube. Özek et al. [10] studied modelling of air conditioning system by fuzzy logic approach, because one of the main problems in control systems is the difficulty to form the mathematical model associated with the control mechanism. They realized that the fuzzy logic without using mathematical model of control system can create control mechanism only with the help of linguistic variables. Kim et al. [11] examined an electrical modelling of the fuel cell generation system. They used fuzzy logic controller to overcome inherent disadvantages such as uncontrollable large overshoot and large current ripple. They noted that fuzzy
controller is very effective in output control and desired operating point operation, which in turn offers high system stability and performance. Tong et al. [12] studied about 1 kW PEM fuel cell unit and developed the models of stack voltage, cathode flow, anode flow. They proposed that the power demand of the external load can be provided by the fuel cell stack under the control of a real-time simplified variable universe fuzzy controller. Tiryaki et al. [13] studied about dishwasher which is frequently used in daily life is modelled and simulated by using fuzzy logic. They concluded that if an appropriate hardware support and appropriate sensors are provided for the dishwasher, with the aim of the fuzzy logic model the washing process may be done without human intervention according to the inputs such as quantity of the dishes, type of the dishes by the machine.

In this experimental study, three different plate combinations compared in terms of HHO dry cell performance. Also in this study, Rule-based Mamdani-type fuzzy modeling used to evaluate performance of HHO dry cells with different plate combination. Performance parameters are plate numbers, time, current and temperature. Study includes fuzzification of input variables, representation of fuzzy set with 9 linguistic variables, formation of rule basis and a comparison between output values obtained by experiments and by calculation based on generated rules and RBMTF technique.

II. MATERIALS AND METHODS

Fuzzy logic is a superset of Boolean-conventional logic that has been expanded to handle the concept of partial truth and truth values between “completely true” and “completely false”. Fuzzy theory should be seen as a methodology to generalize any specific theory from crisp to continuous. Fuzzy modelling opens the possibility for straightforward translation of statements in natural language-verbal formulation of the observed problem-into a fuzzy system. Its functioning is based on mathematical tools [14].

Fuzzy inference system consists of a fuzzification interface, a rule base, a database, a decision-making unit, and finally a defuzzification interface. The function of each block is as follows. A rule base containing a number of fuzzy IF–THEN rules, a database which defines the membership functions of the fuzzy sets used in the fuzzy rules, a decision-making unit which performs the inference operations on the rules, a fuzzification interface which transforms the crisp inputs into degrees of match with linguistic values and a defuzzification interface which transforms the fuzzy results of the inference into a crisp output. Mamdani's method is the most commonly used in fuzzy inference system, due to its simple structure of 'min-max' operations. Mamdani's method can be used is widely used in fields which require specialized knowledge and is a fuzzy logic method that can be applied to any solution of all kind of problem [15].

The knowledge base of RBMTF is a collection of fuzzy IF-THEN rules. The term fuzzy logic denotes a modelling approach, where functional dependencies between the input and output variables are described by means of a set of IF-THEN rules following the reasoning with the operators AND, OR and NOT in general linguistic usage. RBMTF is a type of fuzzy relational model where each rule is represented by an IF–THEN relationship. [16].

The aim of this experimental study is to compare different plate combination for HHO dry cell performance and to model fuzzy logic method. With the aid of experimental data, HHO dry cell performances at different plate combination in terms of current and temperature were modeled with Rule-Based Mamdani-Type Fuzzy (RBMTF) modeling technique. RBMTF was designed using MATLAB fuzzy logic toolbox. In the developed RBMTF system, output parameter current and temperature was determined using inlet parameters plate numbers and time. Hereafter the rules, which are used to detect the behavior of the fuzzy logic controller and the relationship between system’s input and output, are determined. As a result of these rules, every value obtained from the experimental study is also determined by fuzzy logic too.

III. RESULTS AND DISCUSSION

In this experimental study which is used to detect HHO dry cell performance; the effect of the plate number and time on current and temperature is investigated. Experimental system was set to 5 minutes. Current and temperature values are obtained on every plate from 60th second to 300th second by 60 second intermittently in the experimental study. The aim of this study with the aid of experimental data, HHO dry cell performances in terms of current and temperature were modeled with fuzzy logic modeling technique. In the developed RBMTF system, output parameters A and T were determined using inlet parameters plate number and t.

Figs. 1-2 shows respectively comparison of experimental data for 9x9 cm², 10x10 cm² and 11x11 cm² plate dimensions for current and temperature.

Fig. 1 Comparison of experimental data for the variation of time with plate number of current values for different plate dimension
These figures present that:
- 11x11 cm$^2$ and 10x10 cm$^2$ has more better performance than 9x9 cm$^2$.
- In the case of each plate temperature increases by the course of time and the current value decreases by the increasing plate number.
- According to the experiments, high temperature has been found 29 °C, 32 °C and 33 °C and current density has been found 0.02 A/cm$^2$, 0.023 A/cm$^2$ and 0.024 A/cm$^2$ for 9x9 cm$^2$, 10x10 cm$^2$ and 11x11 cm$^2$ respectively (Figs 1-2).

Figs. 3-8 shows respectively comparison of experimental data with RBMTF for the variation of time with combination of current and temperature values for 9x9 cm$^2$, 10x10 cm$^2$ and 11x11 cm$^2$ plate dimensions (plate number = 1-10; t = 60-300 s). From a comparison of the experimental results with the results of the fuzzy logic study, one can see that the results are quite compatible (Figs. 3-8).
Figs. 3-8 present that:

- For 9x9 cm², the maximum current value is 1.07 A at 9-7 combination and 300 s. For 10x10 cm², the maximum current value is 1.2 A at 11-9 combination and 300 s. For 11x11 cm², the maximum current value is 1.25 A at 11-9 combination and 300 s.
- For 9x9 cm², the minimum current value is 0.1 A at 9-1 combination and 60 s. For 10x10 cm², the minimum current value is 0.11 A at 11-1
combination and 60 s. For 11x11 cm², the minimum current value is 0.13 A at 11-1 combination and 60 s.
- For 9x9 cm², the maximum temperature value is 29 °C at 9-7 combination and 300 s. For 10x10 cm², the maximum temperature value is 32 °C at 11-9 combination and 300 s. For 11x11 cm², the maximum temperature value is 33 °C at 11-9 combination and 300 s.
- For 9x9 cm², the minimum temperature value is 22 °C at 9-1 combination and 60 s. For 10x10 cm², the maximum temperature value is 23 °C at 11-4 combination and 300 s. For 11x11 cm², the maximum temperature value is 23 °C at 11-4 combination and 300 s.

The comparison between experimental data and fuzzy logic is done using statistical methods such as the coefficient of multiple determination (R²) are defined as follows, where n is the number of data patterns, yp,m indicates the predicted, tm,m is the actual value of one data point m, and t̄m,m is the mean value of all actual data points [17]. When Table I is observed, it is found that actual values and the values from fuzzy technique are very close to each other.

\[ R^2 = 1 - \frac{\sum_{m=1}^{n} (t_{m,m} - y_{p,m})^2}{\sum_{m=1}^{n} (t_{m,m} - \bar{t}_{m,m})^2} \]  

TABLE I 
COMPARISON OF DIFFERENT PLATE DIMENSIONS FOR CURRENT AND TEMPERATURE

<table>
<thead>
<tr>
<th>HHO Dry Cell Plate Dimensions</th>
<th>R²</th>
<th>Current (A)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9x9 cm²</td>
<td>98.49%</td>
<td>98.23%</td>
<td>97.2%</td>
</tr>
<tr>
<td>10x10 cm²</td>
<td>98.6%</td>
<td>98.49%</td>
<td>97.8%</td>
</tr>
<tr>
<td>11x11 cm²</td>
<td>98.23%</td>
<td>98.49%</td>
<td>97.5%</td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

In this study, HHO dry cell performances at different plate combinations in terms of current and temperature were experimentally investigated. For HHO dry cell, 11x11 cm² and 10x10 cm² has better performance than 9x9 cm². With the aid of experimental data, HHO dry cell performances at different plate combination in terms of current and temperature were modeled fuzzy logic technique. In the developed RBMFTF system, output parameters A, T was determined using inlet parameters plate number and t. Every value obtained from the experimental study is also determined by fuzzy logic too. The comparison between fuzzy logic and experimental data is done using statistical methods. R² is calculated for the current value 98.49% at 9x9 cm², 98.6% at 10x10 cm² and 98.23% at 11x11 cm². R² is calculated for the temperature value 97.2% at 9x9 cm², 97.8% at 10x10 cm² and 97.5% at 11x11 cm². The actual values and RBMFT results indicated that RBMFT can be successfully used for the specification HHO dry cell performances at different plate combination.

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A Wind Power Plant Feasibility Study for Bursa, Gemlik Region in Turkey by Windsim Software

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Abstract—Development of technology and industry has been causing a remarkable energy demand all around the world. In order to meet this huge energy demand, conventional energy sources are being used a lot and this issue brings along a serious environmental pollution. Especially, last decades many countries have signed the agreements to prevent environmental pollution. In conjunction with these events, renewable energy sources have become important. In this context, most of countries have been increasing the incentives to the clean energy systems. Also, Turkey has been increasing the incentives to renewable energy investments; therefore renewable energy usage is increasing day by day. In 2015, Turkey’s total installed capacity has reached 72146.7 MW and 42.7% of this amount is met by renewable energy sources. In Turkey most commonly used renewable energy sources are hydroelectric energy, wind energy, solar energy and geothermal energy respectively. In 2013, installed wind energy capacity of Turkey was 2759.6 MW and this capacity reached 4503.2 MW in 2015. It can be deduced from this data, wind power investment in Turkey has been expanding dramatically. In this study, a wind power plant (WPP) feasibility study for Gemlik region in Bursa Province is released by using 5 number of Vestas V90 commercial wind turbines. Also, climatology data obtained from Turkish State Meteorological Service are used for this study and by applying these data to the Windsim software; annual energy production (AEP) and capacity factor of the WPP are calculated. The study shows that, establishment of a WPP which has 30.6 GWh/y AEP and 34.9% capacity factor is feasible.

Keywords—Gemlik, Renewable Energy, Wind Energy, Windsim, Wind Power Plant.

I. INTRODUCTION

Energy demand has been increasing all around the world day by day due to the fact that technology and industry have been growing rapidly. As a result, significant environmental pollution issues and problems have been emerging. In recent years, most of agreements have being signed by many countries in order to prevent environmental pollution such as Kyoto Protocol [1]. The main objective of the Kyoto Protocol is that controlling greenhouse gases emission and struggling for reducing hazardous effects of these gases [2]. In parallel with these agreements, clean energy technologies, sustainability and energy efficiency has become important subject matters. Therefore, the developing countries have been increasing incentives and investments to the clean energy technologies. In addition to that, Turkey as a developing country, has been noticed the importance of the renewable energy technologies and it has been raising the investments to this field [3]. The population of Turkey is about 74 million inhabitants and it is estimated that 75.5% of this remarkable population lives in urban centers [4]. Also, this important population is increasing in conjunction with the technological improvement and as natural consequence of this situation; Turkey’s energy demand is increasing each passing day and it causes huge energy demand in the country. Turkey is a foreign dependent country because domestic fossil reserves are limited and inadequate. In order to decrease foreign dependency, Turkey needs to benefit from renewable energy sources such as wind, solar, hydropower, biodiesel etc. [5]. Wind energy as a renewable energy source has shown a great development across the world since it is clean, sustainable and efficient energy source. In this context, thanks to Turkey’s geographical position Turkey is a rich country in terms of wind energy. According to Turkish Wind Energy Association (TWEA) installed wind energy capacity has reached 4718 MW by the year of 2015 [6]. As shown in Fig.1, amount of wind power plant and naturally wind energy production has been increasing each passing year [7]. According to Turkey’s development plan, Turkey wants to increase the share of renewable energy source usage to at least 30% [8].

Fig. 1 Cumulative wind energy production by years in Turkey [7]

In this study, wind power potential of Bursa Province in Turkey is evaluated. A WPP feasibility study is revealed for Gemlik region in Bursa Province and total energy production of the designed WPP is calculated. The main objective of this study is providing inputs to researchers and encouraging the investors for harvesting wind potential of the region.
II. MATERIALS AND METHODS

The amount of wind power potential is depend on following factors; structure of terrain, wind speed and the distance to the energy transmission lines (ETL). In the first part of this study, wind power potential in Turkey is evaluated. Secondly, Gemlik region in Bursa Province is selected for a wind power plant investment and the wind power potential of the region is evaluated by considering related parameters. In this context, Turkey wind energy potential atlas created by Turkish Electric Affairs Etude Administration is used. Finally, roughness formation and distance to energy transmission lines and transformer stations are analyzed in order to determine whether wind power plant investment is feasible or not.

A. Assessment of Wind Power Potential in Turkey

Thanks to its geographical position, Turkey has a significant wind power potential. The leading regions in terms of wind power potential investment are Marmara and Aegean region in Turkey. According to TWEA report published in 2016, %49.94 of total number of WPP is in Marmara region and 24.82% of this amount is in Aegean region [7]. The wind atlases given by Fig.2 and Fig.3 were used to estimate the wind power potential for 50 meter and 100 meter elevation respectively. According to wind atlases, average wind speed at 50 meter elevation is approximately 6.5-7.0 m/s throughout the country and this value is nearly 7.5 m/s for 100 meter elevation. In Marmara region this parameter changes between 7.0 and 7.5 m/s at 50 meter elevation and this value is pretty sufficient for the WPP investments.

The WPP which have 5 MW capacity or more can be installed in the fields where have 7.5 m/s or more wind speed at 50 meter above ground level [12]. When considered from this aspect, Marmara and Aegean regions are the pretty suitable region for WPP investments.

B. Assessment of Wind Power Potential in Bursa Province

Bursa Province is located between 40 degrees longitude, 28-30 degrees latitude and located in North-western Anatolia, within the Marmara Region. It is the fourth most populous city in Turkey and it is one of the most industrialized metropolitan cities [13].

Wind power potential of Bursa Province was analyzed by using Wind atlases created by Turkish Electric Affairs Etude Administration. As illustrated in Fig. 6 and Fig. 7, average wind speed at 50 meter elevation is 7.0-7.5 m/s in Bursa Province. In addition to that, average wind capacity factor is 30%-35% for the city.
According to Fig. 6 and Fig. 7, coastal areas of Bursa Province have notable wind speed and wind capacity factor. Especially, Gemlik region where located in coastal area of Bursa Province has average 7.0-7.5 m/s wind speed and nearly 35% capacity factor at 50 meter elevation. In the light of these informations, it can be said that Gemlik region is a suitable field for a WPP investment.

III. WIND POWER PLANT FEASIBILITY STUDY

In this section firstly, Windsim software is introduced. Secondly, wind farm layout design is realised by considering roughness formation and distance to ETL and transformer stations in Gemlik region. Finally, annual energy production and capacity factor of the designed wind farm are calculated.

A. Windsim Software

Windsim is one of the popular wind farm design tools which developed by a Norway company named Windsim AS [15]. The software is based on the Reynolds Averaged Navier-Stokes equations of the Atmospheric Boundary Layer and by solving these equations; the correlation is provided [16]. The calculation steps of Windsim software is shown in Fig. 8. Three inputs; terrain data, roughness map and meteorological data are defined to the software as inputs. Then, solutions are obtained by using computational fluid dynamics (CFD) method.

B. Wind Farm Layout Design

Wind farm site selection is carried out by considering roughness formation and distance to ETL in Gemlik region. For this purpose, the roughness map of Bursa Province was used as shown in Fig. 9. According to Fig. 9, most part of Bursa Province containing Gemlik region is feasible for the WPP investments.

Energy transmission lines and transformer stations in Bursa Province is given in Fig. 10. As shown in Fig. 10, there is a transformer station which is rather close to Gemlik region and it is vital parameter for an economical WPP investment due to the fact that it will reduce the initial investment cost.

After analyzing of the roughness formation and distance to ETL and transformer stations in Gemlik region, a wind farm site selection for WPP investment was realised. As shown in Fig. 11, hillside of Gemlik region was chosen for a WPP feasibility study.
5 Vestas V90 commercial wind turbines were installed in the selected region for numerical analysis. The locations of the installed wind turbines are given in Fig. 12.

Wind turbine layout design was carried out by considering wake affect which decrease the energy efficiency of the wind turbines. Turbine layout was performed by considering wind turbine layout proposal as shown in Fig. 13 in order to decrease wake effect.

In addition to the wake affect, energy analysis of the designed wind farm was implemented by considering the air density change with elevation. Energy analysis results of the WPP were obtained as given in Table I. According to Table I, annual energy production (AEP) and capacity factor of the designed WPP were calculated as 30.6 GWh/y and 34.9% respectively. Also, wake loss of the wind farm is 2.301% and it is a satisfactory value for the energy efficiency.

### TABLE I

<table>
<thead>
<tr>
<th>AEP (GWh/y)</th>
<th>Full load hours</th>
<th>Capacity Factor (%)</th>
<th>Wake loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30.6</td>
<td>3055</td>
<td>34.9</td>
<td>2.301</td>
</tr>
</tbody>
</table>

### IV. CONCLUSIONS

Turkey’s economy has been growing very fast, and this important growth causes a huge energy demand in the country. Turkey as a developing country has noticed the important of the energy to provide the continuity of the production and combat with the other countries. That is why Turkey has been increasing the incentives and the investments towards the renewable energy systems. Wind energy as a renewable energy sources has a vital importance for Turkey’s future since Turkey has a remarkable wind power potential thanks to its geographical position. If the country benefit efficiently from this remarkable source, it will be able to reach the energy management objectives and goals.

In this study, a WPP feasibility study for Gemlik region in Bursa was realised. According to feasibility study, investment of a WPP which has 30.6 GWh/y AEP and 34.9% capacity factor is feasible by 5 number of commercial Vestas V90 wind turbine. However, cost analysis of the designed WPP was not considered in this study. Also, only one analysis was performed to estimate the economical aspect of the WPP. If the cost analysis is done and the numbers of analyses are increased, more reliable results can be obtained.

### V. ACKNOWLEDGEMENT

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Thermodynamic analysis of the Organic Rankine Cycle and the effect of refrigerant selection on cycle performance

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Abstract - The Organic Rankine cycle is a power-generation system for lower temperature ranges in which organic fluids with hydrocarbon components are used instead of water. Organic Rankine Cycles, which are suitable for heat recovery applications at low temperatures, can be used for generating electric energy from various waste heat sources. In this study, a thermodynamic analysis is conducted on an example Organic Rankine Cycle that is used to generate electric energy from a geothermal source. The working fluid to be used in the cycle was selected as R134a, R236fa, R245fa and R600a, which are commonly used. For these selected organic fluids, the required cycle performance to generate 1 MW of energy from the turbine was analyzed according to the geothermal source temperature (90-140°C), and the thermal efficiency of the cycle was calculated. The obtained results are presented comparatively with the help of the graphs. R245fa was defined to be more appropriate for the cycle as a refrigerant at constant work conditions.

Keywords - Organic Rankine Cycle, refrigerant, thermodynamic analysis, cycle performance, thermal efficiency

I. INTRODUCTION

Steam power plants are cycles that use water as refrigerant. Thermodynamic model of these power plants is the Rankine cycle. Rankine cycle transforms thermal energy into work. Water is commonly used in the cycle as a refrigerant and it is preferred in medium and big-size power plants for the generation of electric power.

Whereas the water has significant properties such as being safe, environment-friendly and it can enable high heat transfer, it also has certain disadvantages. Some of these disadvantages are that; it is highly corrosive and it has a rather high freezing temperature. Tchanche et al. [1] investigated the physical and chemical properties, the advantages and disadvantages of water and organic fluids.

In recent years, higher-molecular mass hydrocarbon compound fluids have been used in Rankine cycle instead of water. With the use of these fluids, the systems have been referred to as the Organic Rankine cycle and they have been included in the power generation processes that are most common in thermal, solar and geo-thermal power etc. applications in factories [2]-[4].

Yamamoto et al. [10] showed that; in Rankine cycle, the utilization of the fluid R123 instead of water could provide a higher performance value. Lui et al. [11] investigated the impact of the critical temperature of organic fluids on performance. Teng et al. [12] classified the organic dry type fluids.

R245fa, which is one of the isentropic fluids, have become popular recently and there are numerous theoretical and experimental studies on it [13]-[14]. Cihan [15] modeled a system in which the organic Rankine cycle that operates with low-temperature waste heat is combined with the traditional vapor-compression refrigeration cycle. He used R600, R600a and R601 as fluid.

Pulyaev et al. [16] conducted the thermodynamic analysis of the generation of electricity through the organic Rankine cycle by making use of the waste heat that comes out during the transfer of the natural gas to the turbine once it has been pressurized in the combined cycle plant. Ozden and Paul [17] investigated the Sarayköy Geothermal Power Plant which generates electricity through the organic Rankine cycle.

THERMODYNAMIC PROPERTIES OF CERTAIN ORGANIC FLUIDS

<table>
<thead>
<tr>
<th>Organic Fluid</th>
<th>Molecular Mass (g/mol)</th>
<th>Critical Temperature (K)</th>
<th>Critical Pressure (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R123 (CHCl₃CF₃)</td>
<td>152.93</td>
<td>456.8</td>
<td>3.66</td>
</tr>
<tr>
<td>R134a (CF₂CH₂F)</td>
<td>102.03</td>
<td>374.2</td>
<td>4.06</td>
</tr>
<tr>
<td>R152a (CH₂F₂)</td>
<td>66.05</td>
<td>386.2</td>
<td>4.52</td>
</tr>
<tr>
<td>R236fa (CF₂CH₂F₃)</td>
<td>152.04</td>
<td>398.1</td>
<td>3.20</td>
</tr>
<tr>
<td>R245fa (CH₃F)</td>
<td>134.05</td>
<td>427.2</td>
<td>3.64</td>
</tr>
<tr>
<td>R600a (C₃H₁₀)</td>
<td>58.10</td>
<td>408.1</td>
<td>3.65</td>
</tr>
<tr>
<td>R717 (NH₃)</td>
<td>17.03</td>
<td>405.4</td>
<td>11.3</td>
</tr>
</tbody>
</table>

TABLE I
This paper discusses the thermodynamic analysis of a sample Organic Rankine cycle that generates electric power through a geothermal resource. The fluids to be used in the cycle were determined as R134a, R236fa, R245fa and R600a. For these organic fluids, the cycle performance required to obtain 1 MW work from the turbine was analyzed based on the temperature of the geo-thermal resource (90-140°C) and the thermal efficiency was measured. R245fa was defined to be more appropriate for the cycle as a refrigerant at constant work conditions.

II. MATERIAL AND METHOD

A. Organic Rankine Cycle

Organic Rankine cycles function with the same principle as Rankine cycles in terms of thermodynamics. The only difference between Organic Rankine cycles and Rankine Cycles is the fact that; the fluid is an organic fluid that evaporates in lower temperatures compared to water. The cycle consists of a pump, evaporator, turbine and condenser. The turbines used in Organic Rankine cycles only need a single step expansion and thus, they are more practical and economical compared to the conventional steam turbines.

The schematic diagram of the organic Rankine cycle used to generate electric power from various thermal sources (such as bio-mass, geo-thermal, exhaust gases etc.) is given in Fig. 1. The Fig. 2 presents the T-s diagram of the cycle.

Fig.1 Schematic diagram of the Organic Rankine cycle

Fig. 2 T-s diagram of the Organic Rankine cycle

An Organic Rankine cycle technology that is based on the system that generates electricity from heat uses the heat of the hot source in order to evaporate the organic fluid inside the evaporator. The pressurized vapor is then delivered to the turbines. The fluid that is in vapor state at high temperature and pressure expands isentropically in the turbine, it rotates the turbine shaft attached to the electric generator and produces work. The pressure and temperature of the vapor are reduced during this process and they take their last states to enter the condenser. The vapor that comes out of the turbine is mostly a saturated liquid-vapor combination that is highly dry. Then the vapor gives heat to a lake, river or to the atmosphere in a condenser which is a great heat exchanger, indeed and gets condensed at constant pressure.

The vapor that comes out of the condenser as a saturated liquid enters into the pump and here, it is isentropically compressed up to the evaporator operating pressure. Due to the slight reduction observed in the specific volume of the fluid, the temperature of the fluid increases slightly. The organic fluid that comes out of the pump enters into the evaporator as a compressed liquid and it completes the cycle.

B. Thermodynamic Analysis of the Organic Rankine Cycle

For the thermodynamic analysis of the Organic Rankine cycle, the first law equations were used to estimate the performance of each element in the cycle and to detect the thermal efficiency of the cycle [18]-[20].

1) Turbine: As isentropic expansion occurs in the turbine between 1 and 2s,

\[ Q_{12s} = 0 \quad , \quad s_1 = s_2 \]  

If the first law of thermodynamics is applied on the turbine,

\[ Q_{12s} - W_{T12s} = h_{2s} - h_1 = \dot{m} (h_{2s} - h_1) \]  

Necessary arrangements are made to calculate the isentropic turbine work through the following equation:

\[ W_{T12s} = \dot{m} (h_1 - h_{2s}) \]  

The actual turbine work and the actual enthalpy value at the turbine exhaust from 1 to 2 is calculated through the following equation:

\[ \eta_{T, isen} = \frac{W_{T12}}{W_{T12s}} = \frac{(h_1 - h_2)}{(h_1 - h_{2s})} \]  

In this equation; \( W_{T12} \) means the isentropic turbine work, \( W_{T12s} \) means the actual turbine work and \( \eta_{T, isen} \) means the isentropic efficiency of the turbine.

2) Condenser: Between 2 and 3, the heat is emitted from the condenser at constant pressure and there is no work exchange during this time.

\[ W_{23} = 0 \]  

\[ Q_{con} = Q_{23} = \dot{m} (h_2 - h_3) \]  

The heat emitted at the condenser is delivered to the cooling water at thermal power plants. Thus; the amount of cooling water required for the condensing process is calculated through the following equation:

\[ Q_{con} = \dot{m}_w c_w (T_{in} - T_{out}) \]
In this equation; \( m \) means the amount of the cooling water, \( c \) means the specific heat of the cooling water, \( T_{in} \) and \( T_{out} \) mean the inlet and outlet temperatures of the cooling water.

3) Pump: Between 3 and 4s, isentropic compression occurs in the pump. The fluid used in the pump is deemed as an incompressible fluid (\( v_3 = v_4s = \text{constant} \)) and the specific work (the work required to compress unit mass of working fluid) of the pump is calculated through the following equation:

\[
-w_{P34s} = \int v \, dP = v_3 (P_4 - P_3) = h_{4s} - h_3
\]

As in this expression the specific volume of the fluid and the inlet-outlet pressures of the pump are known, the specific work of the pump is easily found. Also by making use of the equation (8), the specific pump work is found and the enthalpy of the fluid at the outlet of the pump is calculated through the following equation:

\[
h_{4s} = v_3 (P_4 - P_3) + h_3
\]

The actual pump work between 3 and 4 and the enthalpy value at the outlet of the pump is calculated through the following equation:

\[
\eta_{P,isen} = \frac{\dot{W}_{P34s}}{\dot{W}_{P34}} = \frac{(h_{4s} - h_3)/(h_4 - h_3)}{(h_{3s} - h_3)/(h_4 - h_3)}
\]

In this equation; \( \dot{W}_{P34s} \) is the isentropic pump work, \( \dot{W}_{P34} \) is the actual pump work and \( \eta_{P,isen} \) is the isentropic efficiency of the pump.

4) Evaporator: Between 4 and 1, the hot source is used to deliver heat to the organic fluid at constant pressure. The amount of heat delivered to the evaporator is calculated through the following equation:

\[
\dot{Q}_{vap} = \dot{m} (h_1 - h_4)
\]

The amount of heat delivered to the evaporator from the hot source is calculated through the following equation:

\[
\dot{Q}_{vap} = \rho_{\text{water}} V_{\text{water}} C_{\text{water}} \Delta T
\]

Here; \( \Delta T \) is the temperature difference between the hot source and its surrounding.

5) Thermal Efficiency of the Cycle: When performing the thermal calculations of the elements that make up the cycle, the thermal efficiency of the cycle is calculated through the following equation:

\[
\eta_{\text{thermal}} = \frac{\dot{W}_{\text{net}}}{\dot{Q}_{\text{vap}}} = (\dot{W}_{T12} - |\dot{W}_{P34}))/\dot{Q}_{\text{vap}}
\]

III. RESULTS AND DISCUSSION

The design parameters and working conditions to be used for the thermodynamic analysis of the system elements are presented in Table II.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal resource temperature</td>
<td>90-140°C</td>
</tr>
<tr>
<td>Turbine inlet temperature</td>
<td>85-135°C</td>
</tr>
<tr>
<td>Turbine power</td>
<td>1 MW</td>
</tr>
<tr>
<td>Condensing temperature</td>
<td>30°C</td>
</tr>
<tr>
<td>Turbine isentropic efficiency</td>
<td>75%</td>
</tr>
<tr>
<td>Pump isentropic efficiency</td>
<td>80%</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>20°C</td>
</tr>
</tbody>
</table>

In the thermodynamic analysis that was made using the parameters given in Table II, the turbine inlet temperature was defined based on the temperature of the geothermal resource and was taken as 5°C lower than the temperature of the geothermal resource. As for the turbine inlet pressure, saturation pressure was taken as 10°C lower than the temperature of the geothermal resource.

Based on the temperature of the geothermal resource, variation of flow rate of refrigerant that is required to obtain 1 MW turbine work is given in Fig. 3 for constant working conditions. As seen in Fig. 3, the flow rates of each four refrigerants decrease based on the increasing temperature of the geothermal resource. R236fa is the fluid with the highest flow rate required for 1 MW turbine work whereas R600a is the fluid with the lowest flow rate.

Based on the temperature of geothermal resource, variation of amount of heat supplied to the evaporator that is required to obtain 1 MW turbine work is given in Fig. 4 for constant working conditions. As seen in Fig. 4, for each of the four refrigerants, the amount of heat supplied to the evaporator from the geothermal resource decreases depending on the increase observed in the temperature of the geothermal resource.

When R245fa and R600a are used in the cycle as refrigerants, the amounts of heat delivered to evaporator depending on the temperature of the geothermal resource are very close to each other and the amount of heat delivered to the evaporator is lower compared to the other two refrigerants. The amount of heat delivered to the evaporator from the geothermal resource is higher when R236fa is used within an approximate range of 95-120°C geothermal resource temperature and when R134a is used outside this range (Fig. 4).
Based on the temperature of the geothermal resource, variation of flow rate of geothermal resource that is required to obtain 1 MW turbine work for different refrigerants. As the pump’s specific heats remains constant at critical pressure, the required pump work decreases depending on the increasing geothermal resource temperature.

Based on the temperature of geothermal resource, variation of amount of heat required to be exhausted from the condenser to obtain 1 MW turbine work is given in Fig. 7 for constant working conditions. For each of the four refrigerants, the amount of heat required to be exhausted from the condenser decreases depending on the geothermal resource temperature. When R245fa and R600a are used as fluids, the amount of heat required to be exhausted from the condenser is higher when R236fa is used within an approximate range of 95-120°C geothermal resource temperature and when R134a is used outside this range (Fig. 7).

For different refrigerants, variation of thermal efficiency of the organic Rankine Cycle that provides the performance required to obtain 1 MW turbine work is given Fig. 8 based on the temperature of geothermal resource. For each of the four refrigerants, the thermal efficiency of the cycle increases
These refrigerants are lower compared to other refrigerants. Hence, the amount of heat exhausted from the condenser are very close to each other and these are lower compared to other refrigerants. R236fa is the fluid with the highest flow rate. R245fa should be preferred as the refrigerant as the thermal efficiency of the cycle would be higher. Normally at constant working conditions when the temperature of the geothermal resource increases the thermal efficiency of the cycle increases as well.

The flow rates of the refrigerant to be used in the cycle show that; the refrigerant with the lowest flow rate that is required to obtain 1 MW turbine work is R600a whereas R236fa is the fluid with the highest flow rate. When R245fa and R600a are preferred as refrigerants, the amounts of heat exhausted from the condenser are very close to each other and these are lower compared to other refrigerants. Hence; the amount of cooling water required for the condensing process is expected to be lower with respect to these refrigerants.

### IV. CONCLUSIONS

There are numerous factors that influence the performance of Organic Rankine cycles. Selection of the refrigerant to be used in the cycle is one of the most significant of these factors. In this analysis performed for the specific conditions, R245fa should be preferred as the refrigerant as the thermal efficiency of the cycle would be higher. Normally at constant working conditions when the temperature of the geothermal resource increases the thermal efficiency of the cycle increases as well.

The flow rates of the refrigerant to be used in the cycle show that; the refrigerant with the lowest flow rate that is required to obtain 1 MW turbine work is R600a whereas R236fa is the fluid with the highest flow rate. When R245fa and R600a are preferred as refrigerants, the amounts of heat exhausted from the condenser are very close to each other and these are lower compared to other refrigerants. Hence; the amount of cooling water required for the condensing process is expected to be lower with respect to these refrigerants.

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Studies on the Energy Efficiency Improvements at Seydişehir ETİ Aluminium Plant

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Abstract - Many industrial processes deal with reducing production costs and energy consumptions. Additionally, increase in energy demand is becoming a highly challenging issue in past decades. Therefore, strategies on significant energy savings in industries are required. Moreover, a great focus on climate change is needed for greenhouse gas emissions.

Seydişehir ETİ Aluminium Plant (SEAP) is a highly energy consumer plant in the regional area. This is mainly due to the current technology used. The alumina refinery commenced mass production by 1973 and the smelter unit started to work in 1974 utilizing Söderberg cell technology (SCT). Previously in SEAP, alumina was manually added to each pot in large quantities. This was labour intensive and harmful to thermal balance and current efficiency. Additionally, it caused more specific energy consumptions and environmental emissions.

Within the modernization of smelter unit, SEAP changed SCT to Pre-baked technology and began to use an "Environmentally-friendly" system. In the process, the pot does not encounter large variations in alumina concentration. This caused a 26.5% reduction in specific energy consumption and decrease in PFC emissions. Furthermore, expansion in production amount, increase in amperage and improved current efficiency were obtained. Another on-going modernization operation in SEAP is the installation of a stationary calciner with high thermal efficiency to replace the conventional rotary kiln. This is expected to bring about 26.1% reduction in specific energy consumption. Moreover, SEAP is planning to change its direct heating technique with live steam injection in the digestion process to decrease the evaporation energy consumption by about 13%.

This study mainly shows the effects of these improvements on energy savings and current efficiencies. Energy and exergy analyses of digestion, evaporation and calcination units in SEAP were also discussed. Recommendations within the study enable the process more efficient, profitable, productive and feasible while having lower energy consumptions.

Keywords - Alumina calcination/electrolysis, bauxite digestion, energy and exergy analysis, Pre-baked technology, Söderberg technology.

Introduction

The Hall-Héroult process is a high temperature process takes place in the smelter unit that has a distinguished mutually dependent relation between the mass and thermal balance. These two effects bring a significant dependence of the system performance on the thermal balance. A well-computed thermal balance provides proper melting of charged materials, keeps the ledge in a desired level, avoids the sludge formation and this will result in better process efficiency [1].

As the operating conditions have been tightened in the past decades due to the requirement for optimization of current efficiency and reducing energy consumption, it becomes more important to keep the thermal balance as stable as at a desired level from operational and control point of view [1].

Bayer process is also highly energy consumer process used for the alumina production that has a remarkable importance on energy efficiency from both an economic standpoint, with the drive to continually reduce operating costs and also from an environmental perspective, with the greater focus on climate change due to greenhouse gas emissions [2].

Seydişehir ETI Aluminium Plant (SEAP) alumina refinery commenced mass production by 1973 and the smelter unit started to work in 1974 with 248 reduction cells in four potlines utilizing Söderberg cell technology (SCT). In the previous years of SEAP, alumina was manually added to each pot in large quantities. This was labour intensive and harmful to thermal balance and current efficiency. Additionally, it caused more specific energy consumptions and environmental emissions.

After a Greenfield investment for the smelter unit modernization, SEAP took the opportunity to convert SCT to Pre-baked technology and began to use an "Environmentally-friendly” system. In the process, the Pre-baked system consists of 94 reduction cells with 300 kA pot capacity and it does not encounter large variations in alumina concentration. This caused a 26.5% reduction in specific energy consumption and decrease in PFC emissions. Furthermore, expansion in production amount, increase in amperage and improved current efficiency were obtained. Another on-going modernization operation in SEAP is the installation of a stationary calciner with high thermal efficiency to replace the conventional rotary kiln. This is expected to bring about 26.1% reduction in specific energy consumption. Moreover, SEAP is planning to change its direct heating technique with live steam injection in the digestion process to decrease the evaporation energy consumption by about 13%.
This study aims to show energy and exergy analysis of the SEAP both Hall-Héroult process and Bayer process take into account SCT and Pre-baked system, boiler house, digestion, evaporation and calcination processes with the following potential improvements:

i. With the conversion of the SCT to Pre-baked system, there is a gain about 10 GJ per tonne of Aluminium metal in terms of electricity usage.

ii. An almost assured energy improvement can be achieved by replacing conventional rotary kiln with stationary calciner with high thermal efficiency, for an energy efficiency gain of 1.5 GJ per tonne of alumina (Al₂O₃).

iii. The indirect digestion heating process should be applied for the SEAP Bayer digestion system to save energy and increase the efficiency. Direct steam injection to the digesters (autoclaves) adds unnecessary dilution that has to be removed by additional evaporation, resulting in capital and operating cost impacts, and production losses. This will enable sending live steam condensate from digestion process back to the boiler house as boiler feed water and the decrease in evaporation discharge liquor caustic concentration range due to the elimination of additional bauxite slurry dilution in digestion.

Basically the analyses of heat flow diagrams of complex chemical processes consider only the first law of thermodynamics. The size of the energy input from an external source is accepted as an absolute measure of a process. A sum of entropy increments of all the heat transfers and assumed to not produce any useful work. As far as only the first law of thermodynamics is taken into consideration, the heat flow diagram heat efficiency is used as the criterion of thermodynamic perfection [3].

The First Law of Thermodynamics is conventionally used to analyse energy consumption and determine the plant performance. However, it comes up short to judge the quality of energy therefore it is required to conduct a overall exergy analysis. Exergy analysis, as a result of the Second Law of Thermodynamics, can measure the quality of energy in a process industry, and has been carried out for various industries [4]. The exergy is a property that determines the useful work potential of a given amount of energy in a specific state [5]. In a wider sense, one can say that exergy is the capacity to do work.

According to the Second Law of Thermodynamics, any heat process is characterized by growth of system entropy. The incremental system entropy can serve as an absolute criterion of thermodynamic perfection in the analysed heat process. A sum of entropy increments of all the heat-using elements defines a supply of energy from an external source, for example, a thermal power station [3].

The thermodynamic analysis of a system can be conducted according to the so-called exergy method [3].

Exergy analysis of a system and its stages includes calculation of exergy losses at any process steps, shares of external exergy losses, and exergy efficiency. Put another way, it is the analysis of size and quality of secondary power resources and expediency of their utilization [3].

I. EXERGY ANALYSIS METHODOLOGY ON A CHEMICAL PROCESS

The exergy of a non-isolated system is the maximum work that can be extracted from this system during a process that brings the system into thermodynamic equilibrium with its environment. By choosing as a surrounding medium for all systems the environment of our planet, exergy, which is measured in energy units, can become a universal measure of the quality of matter and energy. In general, exergy can be defined as the resource consumed by dissipative structures to produce structure/information and remain in states far from thermodynamic equilibrium with their environment or the resource consumed by decaying structures as they proceed to thermodynamic equilibrium with their environment [6].

For matter that is not fuel, the standard chemical exergy (eᵢₒ) can be calculated from its theoretical reaction of formation at the environmental standard state (Tₒ, Pₒ)

\[ aA + xX + yY \rightarrow AaXxYy \]  

(1)

according to relationship

\[ e^0_i, AaXxYy = \Delta G^0_i, AaXxYy (T_o) + \sum v_i e^0_i \]  

(2)

where \( \Delta G^0_i, AaXxYy (T_o) \) is chemical free energy of formation of the substance, \( v_i \) is the stoichiometric coefficient, and \( e^0_i \) is the standard chemical energies of element \( i \) [6].

The standard chemical exergy of elements is related to reference substances found more commonly in the environment and are given in literature [6].

The chemical exergy of solution containing \( n \) chemical species at the environmental state (\( Tₒ, Pₒ \)) is

\[ e_x = \sum n_i e^0_{x,i} = \sum n_i e^0_{x,i} + RT_o \sum n_i ln(y_{x,i})x_i \]  

(3)

The thermomechanical exergy of matter \( e_{p,T} \) which is the exergy of matter due only to its differences in pressure and temperature from the environment, is

\[ e_{p,T} = h - h_o - T_o(s - s_o) = \Delta h - T_o \Delta S \]  

(4)

where \( h, s \) are the specific enthalpy and entropy of matter at \( T, P \) and at \( Tₒ, Pₒ \) [4].

Finally the total exergy of a solution at conditions \( T, P \) different from the environmental state is

\[ e = e_x + e_{p,T} \]  

(5)
Moreover, chemical exergy allows the definition of a thermodynamic efficiency coefficient for any process, based on a simple exergy balance,

$$E_{\text{in}}^{\text{tot}} = E_{\text{out}}^{\text{tot}} + D^{\text{tot}}$$  \hspace{1cm} (6)

where $E_{\text{in}}^{\text{tot}}$, $E_{\text{out}}^{\text{tot}}$ are the total exergy flows entering and exiting the system (a steady state process is assumed), and $D^{\text{tot}}$ is the total exergy losses or exergy consumption or waste heat due to irreversible processes inside the system (internal losses) and between the system and the environment (external losses). According to the Guy-Stolola equation and the Second Law of Thermodynamics

$$D^{\text{tot}} = T_0 \Delta S^{\text{tot}} \geq 0$$  \hspace{1cm} (7)

where $\Delta S^{\text{tot}}$ is the total increase in entropy in both system and environment [4].

By dividing the exergy outflow $E_{\text{out}}^{\text{tot}}$ into products and wastes (e.g., chemical wastes) according to equation

$$E_{\text{out}}^{\text{tot}} = E_{\text{product}}^{\text{tot}} + E_{\text{waste}}^{\text{tot}}$$  \hspace{1cm} (8)

The efficiency of the processes can be defined as

$$\eta_{\text{ex}} = \frac{E_{\text{product}}^{\text{tot}}}{E_{\text{in}}^{\text{tot}}} \quad 0 \leq \eta_{\text{ex}} \leq 1$$  \hspace{1cm} (9)

II. OVERALL EXERGY ANALYSIS OF THE SEAP

In the context of the thermodynamic laws, SEAP both Bayer process and Hall- Héroult process exergy analysis is performed by calculating the chemical exergy values for all the compounds that are used in the process. The Bayer process in total is characterized by very low exergy efficiency as large amounts of exergy are spent solely to achieve the chemical extraction of alumina from the bauxite and the precipitation of alumina as aluminium hydroxide [7]. To understand the reasons for this exergetic inefficiency, a closer look in the process is required. First of all there is an internal inefficiency in the chemical process itself, as in process of boehmite digestion, liquefication, gibbsite precipitation and evaporation, as well as alumina calcination [6]. Similarly, Hall-Héroult process is also one of the great energy consumer which is mainly electricity power, in the process the electrolytic bath is a molten solution of cryolite and alumina.

The SEAP Bayer process is essentially a cyclic process designed to extract the alumina from the boehmite bauxite ore through caustic leaching under high temperature conditions and controlled precipitation, according to the simplified reaction scheme:

$$2\text{Al}_{2}\text{O}_{3} \cdot \text{H}_{2}\text{O} \_{\text{bauxite}} + 2\text{NaOH} \_{\text{aq}} \rightarrow 2\text{NaAlO}_{2} \_{\text{aq}} + 4\text{H}_{2}\text{O} \_{\text{l}} \rightarrow \text{Al}_{2}\text{O}_{3} \cdot 3\text{H}_{2}\text{O} \_{\text{s}} + 2\text{NaOH} \_{\text{aq}}$$

Also the Hall-Héroult process is the electrolytic process to produce molten aluminium. In this process, alumina (Al$_2$O$_3$) is dissolved in a molten cryolite (Na$_3$AlF$_6$) bath at around 960 °C where it is reduced to produce liquid aluminium metal and oxygen ions. The liquid aluminium metal is slightly denser than the electrolyte and is continuously deposited at the bottom of the cell while the oxygen reacts with the carbon anode to form CO$_2$. The simplified overall cell reaction is [8]:

$$2\text{Al}_{2}\text{O}_{3} \_{\text{solution}} + 3\text{C} \rightarrow 4\text{Al} \_{\text{l}} + 3\text{CO}_2 \_{\text{g}}$$

The calculated previous and current overall mass and exergy analysis of the SEAP for 1 tonne liquid aluminium produced is given in below tables and figures.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>BOEHMITE EXTRACTION AND GIBBSITE PRECIPITATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 t of Al (Previous)</strong></td>
<td><strong>1 t of Al (Current)</strong></td>
</tr>
<tr>
<td><strong>INPUT</strong></td>
<td><strong>Mass (t)</strong></td>
</tr>
<tr>
<td>Bauxite</td>
<td>4.14</td>
</tr>
<tr>
<td>NaOH</td>
<td>0.25</td>
</tr>
<tr>
<td>Water</td>
<td>11.76</td>
</tr>
<tr>
<td><strong>TOTAL INPUT (IN1)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>UTILITIES</strong></td>
<td><strong>Coal</strong></td>
</tr>
<tr>
<td>Electricity</td>
<td>1.40 GJ</td>
</tr>
<tr>
<td><strong>TOTAL UTILITIES (IN2)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>PRODUCT</strong></td>
<td><strong>Gibbsite</strong></td>
</tr>
<tr>
<td><strong>TOTAL PRODUCT (OUTL)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>WASTE</strong></td>
<td><strong>Red Mud</strong></td>
</tr>
<tr>
<td>Water</td>
<td>11.76</td>
</tr>
<tr>
<td>CO$_2$ from Coal</td>
<td>1.66</td>
</tr>
<tr>
<td>Steam from Coal</td>
<td>0.36</td>
</tr>
<tr>
<td><strong>TOTAL WASTE (OUT2)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>WASTE HEAT (IN1+IN2-OUT1-OUT2)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total Energy Consumption (Utilites)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Total CO$_2$ Emissions</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Exergy Efficiency of Process</strong></td>
<td></td>
</tr>
</tbody>
</table>

In the SEAP Bayer process, alumina is extracted from boehmitic bauxite with a sodium hydroxide solution, under a pressure of 4 MPa and at elevated temperature (250 °C), in autoclaves (digestion stage). The produced slurry contains dissolved sodium aluminate and a solid residue (red mud), which is removed in thickeners (clarification stage). The aluminate solution is then seeded with gibbsite (aluminium tri hydroxide) at 60 °C to accelerate the precipitation of gibbsite (precipitation step).

Finally the precipitated aluminium hydroxide is removed from the solution and is calcined at 1000 °C to produce powdered, smelter and commercial grade metallurgical alumina (calcination step).
In the Hall-Héroult process, aluminium is produced by the electrolytic reduction of metallurgical grade alumina, which is dissolved in a molten bath consisting mainly of cryolite (Na$_3$AlF$_6$), at a temperature of about 960°C. Consumable carbon anodes and a potential of voltage are employed in the reduction cell to produce molten aluminium.

**TABLE II**

**GIIBBSITE CALCINATION (1000 °C)**

<table>
<thead>
<tr>
<th>INPUT</th>
<th>1 t of Al (Previous)</th>
<th>1 t of Al (Current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (t)</td>
<td>Exergy (GJ)</td>
<td>Mass (t)</td>
</tr>
<tr>
<td>Gibbsite</td>
<td>2.93</td>
<td>0.51 GJ</td>
</tr>
<tr>
<td>TOTAL INPUT (IN1)</td>
<td>2.93</td>
<td>0.51 GJ</td>
</tr>
<tr>
<td>UTILITIES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.51</td>
<td>7.17 GJ</td>
</tr>
<tr>
<td>Electricity</td>
<td>0.18</td>
<td>0.17 GJ</td>
</tr>
<tr>
<td>TOTAL UTILITIES (IN2)</td>
<td>0.54</td>
<td>7.35 GJ</td>
</tr>
<tr>
<td>PRODUCT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td>1.92</td>
<td>0.80 GJ</td>
</tr>
<tr>
<td>TOTAL PRODUCT (OUT1)</td>
<td>1.92</td>
<td>0.80 GJ</td>
</tr>
<tr>
<td>WASTE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam From Gibbsite</td>
<td>1.01</td>
<td>0.64 GJ</td>
</tr>
<tr>
<td>COF From Natural Gas</td>
<td>1.45</td>
<td>0.65 GJ</td>
</tr>
<tr>
<td>Steam From Natural Gas</td>
<td>1.15</td>
<td>0.73 GJ</td>
</tr>
<tr>
<td>TOTAL WASTE (OUT2)</td>
<td>3.62</td>
<td>2.02 GJ</td>
</tr>
<tr>
<td>WASTE HEAT (OUT1-OUT2)</td>
<td>5.04</td>
<td>3.37 GJ</td>
</tr>
<tr>
<td>Total Energy Consumption (Utilies)</td>
<td>7.35 GJ</td>
<td>5.43 GJ</td>
</tr>
<tr>
<td>Exergy Efficiency of Process</td>
<td>14.16 %</td>
<td>13.45 %</td>
</tr>
</tbody>
</table>

**TABLE III**

**TOTAL SEAP BAYER PROCESS**

<table>
<thead>
<tr>
<th>1 t of Al (Previous)</th>
<th>1 t of Al (Current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Energy Consumption</td>
<td>27.93 GJ</td>
</tr>
<tr>
<td>Total CO₂ Emissions</td>
<td>3.11 kg</td>
</tr>
<tr>
<td>Exergy Efficiency of Process</td>
<td>2.59 %</td>
</tr>
</tbody>
</table>

**TABLE IV**

**SEAP HALL-HÉROULT PROCESS**

<table>
<thead>
<tr>
<th>INPUT</th>
<th>1 t of Al (Previous)</th>
<th>1 t of Al (Current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (t)</td>
<td>Energy (GJ)</td>
<td>Mass (t)</td>
</tr>
<tr>
<td>Alumina</td>
<td>1.92</td>
<td>0.80 GJ</td>
</tr>
<tr>
<td>Carbon Anodes</td>
<td>0.55</td>
<td>18.17 GJ</td>
</tr>
<tr>
<td>Cryolite (Na₃AlF₆)</td>
<td>0.04</td>
<td>0.02 GJ</td>
</tr>
<tr>
<td>AFs</td>
<td>0.03</td>
<td>0.03 GJ</td>
</tr>
<tr>
<td>TOTAL INPUT (IN1)</td>
<td>2.53</td>
<td>19.71 GJ</td>
</tr>
<tr>
<td>UTILITIES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>57.24 GJ</td>
<td>2.13</td>
</tr>
<tr>
<td>Fuel for Anode Baking</td>
<td>2.86</td>
<td>8.47 GJ</td>
</tr>
<tr>
<td>TOTAL UTILITIES (IN2)</td>
<td>2.86</td>
<td>65.71 GJ</td>
</tr>
<tr>
<td>PRODUCT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td>1.00</td>
<td>0.00 GJ</td>
</tr>
<tr>
<td>TOTAL PRODUCT (OUT1)</td>
<td>1.00</td>
<td>0.00 GJ</td>
</tr>
<tr>
<td>WASTE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ from Electrolysis</td>
<td>2.04</td>
<td>0.92 GJ</td>
</tr>
<tr>
<td>CO₂ from Anode Baking</td>
<td>0.52</td>
<td>0.23 GJ</td>
</tr>
<tr>
<td>CF₄(g)</td>
<td>5.5×10⁻¹</td>
<td>3.0×10⁻¹ GJ</td>
</tr>
<tr>
<td>CF₂(g)</td>
<td>4.8×10⁻¹</td>
<td>3.6×10⁻¹ GJ</td>
</tr>
<tr>
<td>Spent Post Liners</td>
<td>0.66</td>
<td>1.08 GJ</td>
</tr>
<tr>
<td>TOTAL WASTE (OUT2)</td>
<td>2.62</td>
<td>2.24 GJ</td>
</tr>
<tr>
<td>WASTE HEAT (IN1-IN2-OUT1-OUT2)</td>
<td>55.19 GJ</td>
<td>31.26 GJ</td>
</tr>
<tr>
<td>Total Energy Consumption</td>
<td>84.58 GJ</td>
<td>62.10 GJ</td>
</tr>
<tr>
<td>Exergy Efficiency of Process</td>
<td>35.12 %</td>
<td>47.67 %</td>
</tr>
</tbody>
</table>

Above calculations are done according to below FIG.1 mass and energy balances of primary aluminium production.

![Fig. 1 Mass & energy balances in current industrial process of primary aluminium production](image)

Fig. 2 Exergy analysis of the current industrial process for primary aluminium production

**TABLE V**

**PRIMARY PRODUCTION OF 1 T OF ALUMINIUM**

<table>
<thead>
<tr>
<th>1 t of Al (Previous)</th>
<th>1 t of Al (Current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Energy Consumption</td>
<td>112.51 GJ</td>
</tr>
<tr>
<td>Total CO₂ Emissions</td>
<td>7.85 kg</td>
</tr>
<tr>
<td>Exergy Efficiency of Process</td>
<td>%= 28.80</td>
</tr>
</tbody>
</table>
evaporating liquor will be significantly decreased. The current situation and expected future conditions are shown in Fig. 3. In the SEAP Bayer Process the evaporation area uses steam at 6.5 bar pressure and a temperature of 190 °C, supplied from the boiler house.

![Image](40x562 to 292x719)

**Fig. 3** Evaporation discharge liquor caustic concentration vs. specific steam consumption

The SEAP calcination area can be somewhat quantified, with existing rotary kiln technology achieving typically 3.5 – 4.5 GJ/tAl₂O₃, while the more modern stationary calciner achieve 2.8 GJ/tAl₂O₃. That is why SEAP has already determined the need for investment on a new type stationary calciner to replace the high energy consuming rotary kilns. The comparison of energy consumption of rotary kiln and stationary calciner technology is given below [9, 10]:

**TABLE VI**

<table>
<thead>
<tr>
<th>SEAP CURRENT AND FUTURE CALCINATION PROCESS HEAT BALANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TABLE VI</strong></td>
</tr>
<tr>
<td><strong>Existing Rotary Kiln</strong></td>
</tr>
<tr>
<td><strong>Existing Rotary Kiln</strong></td>
</tr>
<tr>
<td><strong>New Stationary Calciner</strong></td>
</tr>
<tr>
<td><strong>New Stationary Calciner</strong></td>
</tr>
<tr>
<td><strong>Netted Gas Reaction (Net)</strong></td>
</tr>
<tr>
<td><strong>Alpha Reaction</strong></td>
</tr>
<tr>
<td><strong>Air Sensible Heat</strong></td>
</tr>
<tr>
<td><strong>Fuel Sensible Heat</strong></td>
</tr>
<tr>
<td><strong>Total Input</strong></td>
</tr>
<tr>
<td><strong>Netted Gas Reaction (Net)</strong></td>
</tr>
<tr>
<td><strong>Alpha Reaction</strong></td>
</tr>
<tr>
<td><strong>Air Sensible Heat</strong></td>
</tr>
<tr>
<td><strong>Fuel Sensible Heat</strong></td>
</tr>
<tr>
<td><strong>Total Output</strong></td>
</tr>
<tr>
<td><strong>Free Water Vapouration</strong></td>
</tr>
<tr>
<td><strong>Steam Vapouration</strong></td>
</tr>
<tr>
<td><strong>Steam Sulphate Heat</strong></td>
</tr>
<tr>
<td><strong>Steam Sulphate Heat</strong></td>
</tr>
<tr>
<td><strong>Total Energy</strong></td>
</tr>
<tr>
<td><strong>Energy Output</strong></td>
</tr>
</tbody>
</table>

The newly built SEAP Pre-baked system consume 1300 kWh (DC) electricity, 0.41 t carbon anodes per tonne of liquid aluminium metal, compared with the previous Söderberg system which used to consume 1600 kWh (DC) electricity, 0.55 t carbon anodes per tonne of liquid aluminium metal, nearly 19 % reduction in electricity consumption and about 27 % decrease in carbon anode usage. Also the benefits of reasonable thermal balance should be beard in mind.

**IV. CONCLUSIONS**

The exergy analysis preformed in this study clearly indicates that radical changes are needed both in digestion and calcination processes, in order to achieve major benefits supported with the latest technological opportunities in the energy and exergy efficiency of the industry. In this study energy intensive areas in the SEAP Bayer process and the increment of energy efficiencies with possible improvements for each process step is showed. The contribution of the proposed improvements on energy efficiency for both digestion and calcination processes were evaluated and the total benefits in terms of exergetic efficiencies were determined.

Within the modernization of smelter unit caused a 26.5% reduction in specific energy consumption. This has facilitated expansion in production amount, increase in amperage, improved current efficiency and reduction in specific energy consumption and decrease in PFC emissions [11]. Therefore, the cell does not encounter big changes in alumina concentration which extremely help improving performances.

Currently total energy consumption of SEAP Bayer process is around 14.6 GJ/t Al₂O₃, which is slightly higher compared to other boehmitic bauxite processing alumina refineries. The roadmap for SEAP is to perform major changes in the calcination and digestion units. For this reason, SEAP has initiated the replacement of existing rotary kilns with stationary calciner to bring down energy consumption of its calcination process from 3.8 to 2.8 GJ/t Al₂O₃, which also means nearly a 26 % reduction in specific energy consumption.

In the near future, SEAP will change its direct heating technique with live steam injection in the digestion process to indirect heating system to decrease evaporation energy consumption by about 1.4 GJ/t Al₂O₃, and increase the productivity of boiler house by using less live steam for heating of boiler feed water.

The total gain for SEAP in terms of energy savings will be about 2.5 GJ/t Al₂O₃ and exergy efficiency of the process will be improved nearly 17 %. With its own capability, SEAP produces 1 GJ energy for about 8 US$, therefore the total savings will be around 20 US$/t Al₂O₃ with the 15.4 % internal rate of return (IRR) according to financial analysis. Considering the 2.5 GJ/t Al₂O₃ decrease in total energy consumption in the Bayer process, SEAP will improve its energy efficiency ranking among the alumina production plants in the world at 12 GJ/t Al₂O₃.

**ACKNOWLEDGMENT**

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REFERENCES


Using of Biofuel – Diesel Fuel Blends in a Diesel Engine

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Abstract— In this study, investigated effect on performance, emission and combustion characteristics of fuel obtained with adding bioethanol to safflower oil biodiesel – diesel fuel blends in a diesel engine which has single cylinder, direct injection and water cooling. The prepared test fuels are coded as diesel fuel (DF), BD10 (90% diesel fuel + 3% biodiesel), BDE5 (85% diesel fuel + 10% biodiesel + 5% bioethanol) and BDE10 (80% diesel fuel + 10% biodiesel + 10% bioethanol). Engine tests were performed different engine speeds (1000 min−1 – 3000 min−1, ranges of 200 min−1) at full throttle condition. As the results, observed that engine performance values were effect as negative from biodiesel and bioethanol. HC emission is decreased by adding biodiesel to diesel fuel, and it’s increased some with adding bioethanol. The observed that reduced to smoke emission of using biodiesel, and it’s decreased rather with using bioethanol. NO emission values increased due to biodiesel are decreased by adding bioethanol.

Keywords— Safflower oil, engine performance, exhaust emissions, biodiesel, bioethanol.

I. INTRODUCTION

Biodiesel is a promising substitute for mineral diesel as it is renewable, non-toxic, easily biodegradable and contains physicochemical properties that are very close to that fossil fuel. Therefore, biodiesel has been widely proposed as a substitute for mineral diesel fuel, presenting good results in terms of flammability and lower environmental impacts of exhaust emissions in compression ignition engines [1].

Alcohols have been widely used in compression ignition engines as alternative fuels. Although alcohols are cheaper than standard diesel fuel, there are challenges with respect to utilization of alcohols in diesel engines and blending these fuels with diesel [2]. Because of its high octane number, ethanol (CH₃CH₂OH) is a good spark-ignition engine fuel, but it is true that it has been considered (rather vividly) and experimented also as alternative fuel in diesel engines, as reported in recent review paper [3]. It is a biomass based renewable fuel, which can be produced by alcoholic fermentation of sugar from various vegetable materials or agricultural residues [4].

Labeckas et al. worked effects on combustion, performance and emissions of ethanol–diesel–biodiesel blends. According to results, maximum heat release rate (MHRR), maximum combustion pressure (MCP), NOx, CO emissions and smoke opacity increased with used of blend fuels [5]. Kim et al. investigated effect on exhaust emissions of biodiesel and bioethanol blended diesel fuel on a CRDI engine. Test results showed that biodiesel increased CO and NOx emissions although it decreased THC, smoke and PM emissions. Also CO, THC and NOx emissions were increased, and smoke and PM emissions were decreased by addition bioethanol [6]. Fang et al. tested effects of ethanol-diesel-biodiesel blends on combustion and emissions in premixed low temperature combustion. According to results of their study, blend fuels decreased NOx, smoke emission but, it increased CO and HC emissions. However, MCP and MHRR values increased with used of biofuels [7]. Tse et al. investigated effects on the combustion characteristics and particulate emissions from a diesel engine fueled with diesel-biodiesel-ethanol blends. According to test results, biodiesel and bioethanol increased MCP and MHRR, and they decreased PM emissions [8].

II. MATERIAL AND METHODS

A. Test Fuels

Biodiesel used in tests was produced from safflower seed oil with transesterification method. Also, bioethanol was produced from sugar beet of Cumra Sugar Integrated Plant. The prepared test fuels are coded as diesel fuel (DF), BD10 (90% diesel fuel + 3% biodiesel), BDE5 (85% diesel fuel + 10% biodiesel + 5% bioethanol) and BDE10 (80% diesel fuel + 10% biodiesel + 10% bioethanol). The properties of test fuels are given in Table 1.

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Density at 15°C</th>
<th>Viscosity at 40 °C</th>
<th>LHV MJ/kg</th>
<th>Cetane Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>DF</td>
<td>834.5</td>
<td>2.794</td>
<td>43.14</td>
<td>55.2</td>
</tr>
<tr>
<td>BD10</td>
<td>837</td>
<td>2.855</td>
<td>42.54</td>
<td>55.3</td>
</tr>
<tr>
<td>BDE5</td>
<td>836.4</td>
<td>2.776</td>
<td>41.8</td>
<td>53.8</td>
</tr>
<tr>
<td>BDE10</td>
<td>833.9</td>
<td>2.701</td>
<td>41.06</td>
<td>51.1</td>
</tr>
</tbody>
</table>

B. Test Apparatus

The specifications of the engine used in tests are given in Table 2. An air-cooled pressure sensor (Kistler model 6052C) for measuring in-cylinder pressure, an amplifier (Kistler
model 5018A) and an encoder (Kübler model Sendix 5000) for crank-shaft position, and a data logger (NI model usb6210) for data collection were used in the tests. Exhaust emissions were measured by a Bosch model BEA 350 gas analyzer.

### TABLE III

<table>
<thead>
<tr>
<th>Model</th>
<th>Antor 3LD510</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine type</td>
<td>Four stroke-Direct injection</td>
</tr>
<tr>
<td>Cylinder number</td>
<td>1</td>
</tr>
<tr>
<td>Total cylinder volume, cm³</td>
<td>510</td>
</tr>
<tr>
<td>Diameter x Stroke, mm x mm</td>
<td>85 x 90</td>
</tr>
<tr>
<td>Compression rate</td>
<td>17.5:1</td>
</tr>
<tr>
<td>Max. engine speed, 1/min</td>
<td>3300</td>
</tr>
<tr>
<td>Max. engine torque, Nm</td>
<td>32.8</td>
</tr>
<tr>
<td>Max. engine power, kW</td>
<td>9</td>
</tr>
<tr>
<td>Injector pressure, bar</td>
<td>190</td>
</tr>
</tbody>
</table>

C. Experimental Method

Engine tests were performed at different engine speeds (1000 rpm – 3000 rpm, ranges of 200 rpm) at full throttle condition. In-cylinder pressure values of a minimum of 50 engine cycles at a precision of 1° crank angle (CA) were recorded by a computer using the data-logger.

III. TEST RESULTS

A. Engine Performance

Figure 1 show that changes depending on the engine speed of specifically fuel consumption (SFC) and thermal efficiency values. The SFC values with used of biodiesel were increased 5.7% on average compared to DF, and they were further increased down to 23% on average by used of bioethanol. Both biodiesel and bioethanol decreased thermal efficiency values as down to approximately 14.87% on average.

Figure 2a and 2b show that cylinder pressure and heat release rate resulting at 1400 rpm engine speed obtained at maximum torque. The MCP values of blend fuels were higher than that DF. Especially, bioethanol increased MCP values. Both biodiesel and bioethanol, same way, increased the MHRR values.

B. Combustion Characteristics

Oxygen content in both biodiesel and bioethanol increased combustion rate of fuel. Therefore, blend fuels burned faster than DF, and in this case MCP and MHRR increased. This result were compatible with studies of Alptekin et al. [12], Su et al. [13] and Anbarasu et al. [14].

C. Exhaust Emissions

Figure 3, 4 and 5 show that changes of exhaust emissions. Biodiesel increased NO emissions although it decreased HC and smoke opacity emissions. Biodiesel increased NO emissions as 15.67% on average, decreased HC and smoke opacity values as 22.98% and 3.93% on average respectively, due to its oxygen content. Besides, while bioethanol increased HC emissions as up to 82.14 on average, it decreased NO emissions and smoke opacity values as down to 47.55% and 13.14% on average respectively, due to high combustion rate and low combustion temperature. Yilmaz et al. [2], Rounce et al. [15] and Mofijur et al. [16] also presented similar results in their studies.
The results of this study can explain:

- The use of biodiesel–diesel blends decreased the HC and smoke opacity emissions but increased NO emissions, as the oxygen content of the fuel increased.
- The use of bioethanol increased the HC but decreased NO emissions and smoke opacity.

As results, biodiesel and bioethanol may use in diesel engines by biodiesel and bioethanol mixed with diesel fuel.

ACKNOWLEDGMENT

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The Deployment of Microgrid as an Emerging Power System in Uzbekistan

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Abstract— Last decades with rapidly penetration of distributed energy resources to the power system, the interest on microgrid is growing. Microgrid appears with the development of distributed generations and distributed energy resources, such as PV, wind, microturbines, fuel cell, combined heat and power, etc. A microgrid combines distributed energy resources, storage devices (flywheels, energy capacitors and batteries) and flexible loads, and connected to the power grid via switches. Microgrids as a key component of the smart grid are intended to improve energy efficiency, a reliability of power system and decrease carbon dioxide emissions. Uzbekistan has a huge potential of renewable energy resources, especially in solar energy. In this paper are introduced the concept and operation of microgrid, as well as considered the problems and development perspectives of microgrid in Uzbekistan.

Keywords— microgrid, smart grid, distributed energy resources, distribution generation, Uzbekistan

I. INTRODUCTION

The energy sector is a key infrastructure element of the economy of Uzbekistan. An operation and development of this infrastructure largely determines the living conditions of the population and the country's economic development. The population’s growth and economic development of Uzbekistan as well as in many countries require an increase in demand for electrical energy. On the other hand, meeting the need for electric energy society in the future should be, given the limitations of non-renewable resources, while providing energy stability and significantly reducing the negative impact on the environment. Power systems operation becomes more labor-consuming, which ultimately will require the widespread introduction of intelligence in the interest of safety, economy and efficiency, thereby creating the preconditions for the emergence of "Smart Grid" concept. These problems have led to a new concept of Smart Grid. According to the European Technology Platform of Smart Grids [1], a smart grid (SG) is an electricity network that meets future requirements for energy-efficient and economical operation of the power system through the coordinated management and using modern two-way communications between the elements of electrical networks, power plants, accumulating devices and consumers. Microgrid (MG) is a basic element of SG and as a key component of the smart grid are intended to improve energy efficiency, the reliability of power system and decrease carbon dioxide emissions. The term microgrid refers to the concept of single electrical power subsystems associated with a small number of distributed energy resources (DERs), both renewable and/or conventional sources, including photovoltaic, wind power, hydro, internal combustion engine, gas turbine, and microturbine together with a cluster of loads [2]. Last decades with rapidly penetration of DER to the power system, the interest on MG is growing.

II. MICROGRID DEFINITION AND CONCEPT

The pioneers of MG the Consortium for Electric Reliability Technology Solutions (CERTS) and the European Commission Project Micro-Grid gave the following definitions to MG:

According to the CERTS [3], “Microgrid is the cluster of loads and microsources operating as a single controlled entity and providing both power and heat energy. The microgrids are power electronically interfaced as they enhance the power reliability and quality of the power supply”. A vision of MG by CERTS is illustrated in fig.1.

According to the EU research projects [4], [5]: “Microgrids comprise LV distribution systems with distributed energy resources (DER) (microturbines, fuel cells, PV, etc.) together with storage devices (flywheels, energy capacitors and batteries) and flexible loads”. A vision of MG by EU research projects is illustrated in fig.2.

The main components of MG are:
• distributed generation (DG) sources such as photovoltaic panels, small wind turbines, fuel cells, diesel and gas microturbines etc.;
• distributed energy storage devices such as batteries, supercapacitors, flywheels etc.;
• critical and non-critical loads.
In general, literature analyses [8], [9] identified that microgrid architectures divided into three categories: AC, DC, and hybrid microgrids.

MG can be operated:
1) in stand-alone or islanded mode, if MG operates autonomously;
2) in grid-connected mode, if MG connected to the main grid.

In stand-alone mode, microsources provide loads with necessary power energy and MG never connects to the main grid.

In grid-connected mode, MG remains connected to the main grid either totally or partially and extra power generated in MG can be exchanged with the main grid providing auxiliary services.

MG consists of a group of radial feeders (A, B and C), which could be part of a distribution system architecture and a collection of loads (figure 3). The radial system is connected to the distribution system by a point of common coupling (PCC) via a static switch. The PCC is on the primary side of the transformer and separates main grid from MG. Each feeder has a circuit breaker and microsource controller [6].

Fig. 3 Schematic diagram of the microgrid.

IV. BENEFITS AND ADVANTAGES OF MICROGRIDS


There are several technical benefits of MG:
- the lack of vulnerability of large networks
- power blackouts reduction
- energy loss reduction
- improved voltage quality via coordinated reactive power control and constrained active power dispatch
- relief of congested networks and devices, for example during peak loading through selective scheduling of microsource outputs.

The economic benefits of MG consist:
• higher energy efficiency
• reduced transmission and distribution costs
• minimization of fuel cost
• the small scale of individual investments reduces capital exposure and risk, by closely matching capacity increases to growth in demand.
• the low capital cost potentially enables low-cost entry into a competitive market.

The environmental benefits of MG include:
• reduced emissions of greenhouse gases
• reduced emissions of criteria pollutants.

Researchers note that MG offers a number of important advantages [6], [14], [15]:
• The ability of MG, during a utility grid disturbance, to separate and isolate itself from the utility seamlessly with little or no disruption to the loads within the MG;
• In peak load periods it prevents utility grid failure by reducing the load on the grid;
• Significant environmental benefits made possible by the use of low or zero emission generators;
• The use of both electricity and heat permitted by the close proximity of the generator to the user, thereby increasing the overall energy efficiency;
• MG can act to mitigate the electricity costs to its users by generating some or all of its electricity needs;
• Enhancing the quality of power which is delivered to sensitive loads.

V. DEVELOPMENT ISSUES OF MICROGRID IN UZBEKISTAN

Currently, the majority of energy consumed in Uzbekistan is produced by thermal power plants. At the same time, the main share in the structure of energy consumption belongs to the oil and gas resources. Uzbekistan has substantial proven reserves of organic fuel and a robust hydroelectric potential. It accounts for more than 40% of the entire Central Asia’s natural gas and some 20% of Central Asia’s oil. The proven reserves of condensate oil exceed 350 million tons, of a natural gas reach around 2,000 billion cubic meters, and coal almost 2,0 billion tons. Uzbekistan is among the top ten largest producers of natural gas in the world. Hydrocarbons are the main sources of electricity in Uzbekistan (figure 4).

Experts of the center for economic research believe that country’s proven reserves of hydrocarbons are enough to keep its economy running steadily for the next 20-30 years.

The installed capacity of power plants in Uzbekistan exceeds 12.5 million KW including 10 thermal power plants with a capacity of 11.0 million KW and 29 hydraulic electric stations with capacity of 1.4 million KWh (figure 5) [16].

According to the information of Uzbekistan’s Ministry of Economy, implementation of measures to promote renewable energy resources in the basic sectors of the economy will lead to savings of 250.1 million KWh electric energy, of natural gas – 3 million of cubic meter and heat energy – 20.1 GCal.

The most important factor driving the development of distributed energy in the world as well as in Uzbekistan is the diversification of energy balance by increasing the share of local and alternative energy sources (biomass, renewable energy, etc.), which entails more rational use of strategic resources - hydrocarbons. Therefore, one of the most important areas of energy policy at the present stage is the transition from traditional, centralized model of unified energy system of Uzbekistan with a predominance of large generation sources to a variety of types and forms of harmonious combination of DG in Uzbekistan regions.

Undoubtedly, the development of MG in Uzbekistan requires state support measures aimed at stimulating the expansion of its use. There is required to develop a regulatory
framework providing the development of MG; to create an appropriate methodological basis; to amend the legislation providing customs and tax incentives for the development of MG such as reduction of import duties on equipment, preferential taxation of production.

According to today’s experience and publications, MGs can find its application in Uzbekistan in the major MG market segments such as (i) institutional and campus MGs, (ii) commercial and industrial MGs, (iii) military MGs, (iv) community and utility MGs, (v) island and remote “off-grid” MGs. MG helps the transition from a centralized system using large sources of electricity generation, the use of different types of DER, the most appropriate to natural conditions and features of specific customers.

In the last years some work on the development of renewable energy is carried out in the republic. As part of the regulations and Decrees of the President of the Republic of Uzbekistan from March 1, 2013 # BP-4512 “On measures for further development of alternative energy sources” and # RP-1929 “On creation of the International Solar Energy Institute” Solar Energy Institute established.

The solar PV station with capacity of 130 kW was start of operation on December 7, 2015, in Pap district of Namangan region.

A mobile stand-alone solar power plant with capacity of 1.2 MW has been put into operation in Bukhara region at the beginning of 2016. The station is designed for the continuous provision of energy production facilities and the construction of infrastructure projects Kandym deposits of the Russian company “Lukoil”, staying away from the central power supply networks.

In addition, the works on involving in the fuel and energy balance of renewable energy sources are carried out by Joint Stock Company “Uzbekenergo”. In the medium term, planned construction of solar photovoltaic power plants with a capacity of 100 MW in Samarkand, Namangan and Surkhandarya regions.

VI. CONCLUSIONS

The MG as a basic element of smart grids has an important role to increase the grid efficiency, reliability, and to satisfy the environmental issues. This paper presents the architecture, operation and control of MG.

Uzbekistan has a huge potential for using renewable energy sources and the issues of developing the concept of a microgrid in Uzbekistan have been examined.

The evaluations of gross and technical potentials of renewable energy sources in Uzbekistan give the following conclusions:

- the availability of some types of renewable energy is almost all over the country is required for radical revision of using strategy of national energy resources, both in the near and in the long-term perspective;
- the implementation of MG will be bringing above mentioned technical, economic and social benefits to the economy of Uzbekistan;
- large-scale use of renewable energy sources by switching to a decentralized energy supply would solve a number of problems to improve the energy supply facilities in rural areas, especially in remote inaccessible areas.

REFERENCES


Comparison of CFD and XFOIL Airfoil Analyses for Low Reynolds Number

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Abstract— Blade Element Momentum (BEM) theory is generally used technique for calculation of aerodynamic performance of such turbine application. To obtain close results with blade element momentum theory, aerodynamic data of airfoil has to be as correct as possible. Nowadays, Computational Fluid Dynamics (CFD) is used for optimization and design of turbine application. Lift coefficient, drag coefficient and Lift coefficient over drag coefficient are tried to optimize by XFOIL code results, are compatible with each other until stall angle. Also, lift coefficient over drag coefficient was tried to optimize by changing the airfoil geometry.

Keywords— Xfoil, Computational Fluid Dynamics (CFD), Transition SST k-omega model, low reynold number

I. INTRODUCTION

Airfoil is such an aerodynamic shape and it generates aerodynamic forces. The air passes above and below the wing. Due to the momentum conversation, the speed of air particles on wing’s upper surface increases and also the pressure on the wing’s upper surface decreases due to the energy conversation. Because of that the high air pressure moves toward low air pressure. Air pushes the wing so that the force known as lift force is generated [1].

The point at front of the airfoil is defined as the leading edge. Similarly, the point at behind of airfoil is defined as the trailing edge. The chord length is the characteristic dimension of airfoil section [1].

It is possible to predict aerodynamic performance airfoil by using experimental, Computational Fluid Dynamics (CFD) and a user friendly program such as 2d panel code XFOIL that combines a conformal-mapping method for the design of airfoils with prescribed pressure distributions, a panel method for the analysis of the potential flow about given airfoils, and an integral boundary-layer method [3]. Although experimental and Computational Fluid Dynamics (CFD) methods are more expensive and require longer time than panel method, XFOIL results have less accuracy than experimental and CFD methods due to some assumption.

In this paper, the aerodynamic performance of low Reynolds airfoil SG6040 which is designed exclusively for horizontal wind turbines with small blades [4] is predicted by using XFOIL and ANSYS-FLUENT at two different Reynolds number (Re = 3x10^5, 4x10^6). Firstly, the 2D model of airfoil is generated by using airfoil coordinates. After that, aerodynamic performance of the airfoil is obtained by XFOIL software under General Public License. Domain construction and grid generation for calculating the 2D airfoil performance is described in CFD analysis. Then, the aerodynamic performance is calculated by using CFD methods (in Fluent commercial software). Finally, lift coefficient to angle of attack and drag coefficient to angle of attack of the airfoil obtained by the CFD results, are compared with XFOIL results and also literature.

II. XFOIL AND CFD ANALYSIS

A. SG6040 Airfoil

The low Reynold SG6040 airfoil, investigated in this study, has a maximum thickness of % 16, a camber of 2.5 %. The profile is shown in Fig. 2. This airfoil was designed exclusively for wind turbines with small blades (1-5 kW) [5].

Fig. 1. Basic geometry of airfoil [2]
B. XFOIL

The XFOIL [3] code combines a potential flow panel method and an integral boundary layer formulation for the analysis of the flow around airfoils. The code was developed to rapidly predict the airfoil performance at low Reynolds numbers and its convergence is achieved through the iteration between the outer and inner flow solutions on the boundary layer displacement thickness.

For calculating the airfoil performance in XFOIL coordinates of SG6040 airfoil was loaded to XFOIL. After loading airfoil coordinates, the number of point was defined as 250 point, and also number of iteration was defined as 100 iteration. Then, Reynolds number of the flow was set up as 3x10^5 and 4x10^5. The results were drawn as graph of the lift, drag coefficient versus angle of attack and also pressure distribution around the airfoil can be acquired.

C. CFD Analysis

CFD analysis for aerodynamic performance of SG6043 were carried out by using ANSY-FLUENT. The FLUENT code solves the RANS equations using finite volume discretization. Steady state solver, SIMPLE pressure based solver and Green-Gauss cell based discretization were used in the analysis. Also, second order scheme was used for the momentum and turbulence equations discretization. When applying the CFD analysis to airfoil at low Reynolds numbers, it is difficult to solve boundary layer elements with common turbulence methods. Because of that, more error has been obtained in calculation of drag force. To obtain more correct prediction of drag force, transition turbulence models are more suitable. With SST k-ω turbulence transition model, the results were acquired. The convergence of the numerical solution was controlled by monitoring numerical error of the solution.

O-ring type domain structure was chosen. The external domain is a circle which has a diameter of 25 m. It was defined as a boundary condition of “Velocity Inlet”. The airfoil bottom and top surfaces were defined as “Wall” boundary conditions. The domain which is defined as air which has a density ($\rho$) of 1.225 kg/m$^3$ and dynamic viscosity ($\mu$) of 1.7894e-05 Pa s.

Circular domain was placed 12.5 times of the chord length away from the airfoil. The computational domain and mesh structure were shown in Fig. 3.

Different sizes of grids were used to ensure grid independency of the analysis results. This is achieved by obtaining solution with increasing number of grids nodes until a stage is reached where the solution exhibits negligible change with further increase in the number of nodes.

The convergence rate is monitored during the iteration process by means of the residuals of the dependent variables of the governing differential equation. Convergence is also checked using the relative differences between two successive iterations for each of the integrated force coefficients. In order to resolve the boundary layer, 42 layers in the boundary were introduced and first layer was located 0.005 mm from the wall. Hence, the first grid point of the wall in the normal direction was placed at a distance less than $y^+ = 1$ from the wall. The $y^+$ ($\rho U y / \mu$) is defined as the non-dimensional wall distance for wall-bounded flow in a turbulent boundary layer analysis. To consider the viscous sub layer in the turbulent boundary layer, the value of the $y+$ has to be less than 10 [6, 7]. The detail of the mesh around the airfoil is shown in Fig. 4.

In Fig. 5 and Fig. 6, the comparison of the aerodynamic coefficients of SG6040 in CFD, XFOIL and experimental results [4] at different Reynolds number are shown.
Fig. 5. Comparison of lift coefficient (a) and drag coefficient (b) between CFD, XFOIL and experiment at 3x10^5 Reynolds number.

Fig. 6. Comparison of lift coefficient (a) and drag coefficient (b) between CFD, XFOIL and experiment at 4x10^5 Reynolds number.
For the 0.27 of angle of attack degree at $3 \times 10^5$ Reynolds number and 0.23 of angle of attack degree at $4 \times 10^5$ Reynolds number, the contours of static pressure on SG6040 were obtained. As expected, the pressure on lower surface of airfoil is higher than upper surface, also negative pressure value was obtained on the lower surface.

Hence, the value of coefficient of lift and drag increases with increasing the angle of attack as expected.

III. CONCLUSION

Flow performance characteristics of SG6040 has been computationally investigated at Reynolds number $3 \times 10^5$ and $4 \times 10^5$. The commercial code Fluent with SST k-ω transition and general public license XFOIL, was used for numerical analysis.

The comparison between the experimental literature studies, CFD analysis and XFOIL analysis was analyzed. That the results of XFOIL analyses show as good as agreement with CFD analyses and experiment results, was observed. Although, SST k-ω transition model shows promising results to predict accurate aerodynamic coefficients such as lift ($C_L$) and drag ($C_D$) values, it is clear that XFOIL analysis tool can be used easily to predict aerodynamic performance of airfoils at low Reynolds number for the conceptual design in engineering.

REFERENCES

Mini-Scaled Horizontal Axis Wind Turbine Analysis by Qblade and CFD

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Abstract—The software QBlade under General Public License is used for analysis and design of wind turbines. QBlade uses the Blade Element Momentum (BEM) method for the simulation of wind turbines and it is integrated with the XFOIL airfoil design and analysis. It is possible to predict wind turbine performance with it. Nowadays, Computational Fluid Dynamics (CFD) is used for optimization and design of turbine application. In this study, Horizontal wind turbine with a rotor diameter of 2 m, was designed and objected to performance analysis by QBlade and Ansys-Fluent. The graphic of the power coefficient vs. tip speed ratio (TSR) was obtained for each result. When the results are compared, the good agreement has been seen.

Keywords—QBlade, Computational Fluid Dynamics (CFD), Horizontal wind turbine, Blade Element Momentum (BEM), Wind Energy

I. INTRODUCTION

The importance of the renewable energy sources gradually increases with climate change. One of the renewable energy sources is the wind. Nowadays, the numbers of the green energy systems are increasing day by day and also, the small-scaled wind turbine are designed for the purpose of using at the greenhouse.

Generally, two types of wind turbine are used. One is horizontal wind turbine and another is vertical wind turbine.

Also, the countries’ economic growth is shown parallelism with the amount of the generated energy. In order to resume economic growth, the amount of the generated energy should be increased.

The energy sources based on fossil fuel increases carbon dioxide emission, therefore, studies on alternative energy source like wind and sun are continued.

Fig. 1 (a) is shown that, the amount of the generated energy from wind energy is approximately 432.88 GW until December 2015. Fig. 1 (b) is shown that new wind energy power system having capacity of 63.467 GW was installed in 2015 [1].

Wind turbine can be classified as large, medium, small and small-scaled. Large wind turbines have 50-100 m rotor diameter and they generate energy between 1 to 3 MW. Medium wind turbines have 20-50 m rotor diameter and they generate energy between 100kw to 1 MW. Small wind turbines have 20-50 m rotor diameter and they generate energy between 25kw to 100 kW. Small-scaled wind turbines can be separated three different types as micro, mini and household. Micro-scale wind turbines have 0.5-1.25 m rotor diameter and they generate energy between 0.004 kW to 0.25 kW. Mini-scale wind turbines have 1.25-3 m rotor diameter and they generate energy between 0.25 kW to 1.4 kW. Household wind turbines have 3-10 m rotor diameter and they generate energy between 1.4 kW to 16 kW [1].

It is possible to predict aerodynamic performance of wind turbine by using experimental, Computational Fluid Dynamics (CFD) and Blade Element Momentum (BEM) methods. Experimental and Computational Fluid Dynamics (CFD) methods are more expensive and require longer time than Blade Element Momentum (BEM) method. But, BEM method has less accuracy than experimental and CFD methods due to some assumption.

In this paper, for the horizontal wind turbine with a rotor diameter of 2 m, the aerodynamic performance is predicted by using QBlade and Ansys-Fluent. Firstly, the turbine is designed and aerodynamic performance is obtained by the software QBlade under General Public License. After that, the 3D model of turbine is generated by using CATIA. Domain construction and grid generation for calculating the 3D wind turbine performance is described. Then, the aerodynamic performance is calculated by using CFD methods (Fluent commercial

Fig. 1 (a) Cumulative capacity of wind turbines in 2015 around the world (b) New installed wind turbine capacity in 2015
software). Finally, power curve and torque curve of the turbine obtained by the 3D CFD results, are compared with Qblade results.

II. QBLADE AND CFD ANALYSES

A. Blade Element Momentum Method

Blade element momentum (BEM) theory is widely used in aerodynamic performance predictions and design applications for wind turbines. This theory combines both momentum theory and blade element theory methods. Momentum theory is useful to predict for ideal efficiency and flow velocity. Forces acting on the rotor to produce the motion of the fluid is determined by the mean of momentum theory. Momentum theory does not depend on the blade geometry. However, blade element theory depends on the blade geometry and it determines the forces acting on the blade after the motion of fluid. If these two theories are combined BEM theory, known as strip theory, is obtained and BEM theory defines the relation of rotor performance to rotor geometry. It is necessary to make assumption for the blade element theory and momentum theory.

For momentum theory:

a) Blade operate without frictional drag
b) A slipstream that is well defined separates the flow passing through the rotor disc from that outside disc
c) The static pressure in and out of the slipstream far ahead of and behind the rotor are equal to the undisturbed free-stream static pressure
d) Thrust loading is uniform over the rotor disc
e) No rotation is imparted to the flow by the disc

For blade element theory:

a) There is no interference between successive blade elements along the blade
b) Forces acting on the blade element are solely due to the lift and drag characteristics of the sectional profile of a blade element [2].

The tangential and normal force coefficients in wind turbines can be calculated as the following:

\[ C_T = C_L \sin \phi - C_D \cos \phi \]  
\[ C_N = C_L \cos \phi + C_D \sin \phi \]  

BEM theory equations can be solved as iteratively. There are two iterative variables that are axial and radial induction factors, in BEM theory. These variables can be defined as follows [3].

\[ a' = \frac{1}{4 \sin \frac{\phi}{2} \cos \frac{\phi}{2} \left( \sigma C_T \right)} - 1 \]  

where, \( \phi \) is the inflow angle, \( C_T \) and \( C_N \) is the tangential and normal force coefficient respectively, \( \sigma \) is the solidity which is defined as the ratio of the planform area of the blades to the swept area [4]. It can be expressed as follows:

\[ \sigma = \frac{cB}{2\pi r} \]  

where, \( c \) is the chord length, \( B \) is the number of blades and \( r \) is the disk radius.

Fig. 2 shows the velocity component in the rotor plane. If the axial and radial induction factors are firstly guessed, the inflow angle \( \phi \), can be computed. Then, the angle of attack \( \alpha \), that is the between the chord line of the airfoil and the relative wind speed, can be obtained by using the following equation:

\[ \theta = \theta_p + \beta \]  
\[ \alpha = \phi - \theta \]  

where \( \beta \) is a twist angle of the blade, \( \theta_p \) is a pitch angle of the blade, \( \theta \) is the combination of the twist angle \( \beta \) and the pitch angle \( \theta_p \). After the calculation of the angle of attack, the lift and drag coefficient of the airfoil can be obtained from the lift and drag curves of the airfoil. By using these force coefficients, new induction factors can be calculated and compared to the initial induction factors. When the maximum value of the \( \Delta a \) and \( \Delta a' \) is below the convergence criterion \( e \), it means that the iteration converge. Then, the next element can be calculated.

The flow diagram, which is used to solve iteratively for Axial Induction Factor and the Radial Induction Factor solution of BEM theory is shown in Fig 3.
For an ideal wind turbine blade design, firstly it was decided to design a 2 m blade diameter turbine. SG6043 airfoil type which is designed exclusively for wind turbines with small blades [6] was selected. Tip speed ratio, \( \lambda \), was chosen 5. For SG6043 airfoil, the lift coefficient at the angle of attack 4.5\(^\circ\), where the \( C_L/C_D \) ratio has maximum rate, was acquired as 1.22 from XfIrf software. Blade section was divided 9 parts. Then from the formulas inflow angle, chord length and twist angle were calculated for each section.

The rotor blades parameter and the design parameter of wind turbine are listed in Table 1 and Table 2, respectively.

**TABLE I**

<table>
<thead>
<tr>
<th>Blade</th>
<th>Radius of blade (m)</th>
<th>Number of the blades</th>
<th>Airfoil types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>3</td>
<td>SG6043</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE II**

<table>
<thead>
<tr>
<th>Geometry of Blade</th>
<th>Section</th>
<th>r/R</th>
<th>Chord length (m)</th>
<th>Twist angle (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0.2</td>
<td>0.184</td>
<td>25.50</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.3</td>
<td>0.156</td>
<td>17.96</td>
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<tr>
<td></td>
<td>3</td>
<td>0.4</td>
<td>0.130</td>
<td>13.21</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>0.5</td>
<td>0.110</td>
<td>10.03</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>0.6</td>
<td>0.094</td>
<td>7.79</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>0.7</td>
<td>0.082</td>
<td>6.13</td>
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<td></td>
<td>7</td>
<td>0.8</td>
<td>0.073</td>
<td>4.86</td>
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<tr>
<td></td>
<td>8</td>
<td>0.9</td>
<td>0.066</td>
<td>3.85</td>
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<tr>
<td></td>
<td>9</td>
<td>1</td>
<td>0.059</td>
<td>3.04</td>
</tr>
</tbody>
</table>

The SG6043 airfoil, has a maximum thickness of 10%, a camber of 5.5% and a leading edge radius of 1.7%. The profile is shown in Fig. 4. Also blade model of turbine is shown in Fig 5.

**B. Blade Shape Design for Optimum Rotor with Wake Rotation**

When an ideal rotor is design, the effect of wake rotation is taken into design. The blade shape optimization for ideal rotor includes wake rotation except drag \( (C_D = 0) \) and tip losses \( (F = 1) \). The power coefficient depends on the angle of the inflow angle, \( \varphi \). The power coefficient can be obtained from the following equation:

\[
C_p = \left( \frac{8}{\pi^2} \right) \int_{\varphi_b}^{\lambda} \sin^2 \varphi \left( \cos \varphi - \lambda_r \sin \varphi \right) \left( \sin \varphi + \lambda_r \cos \varphi \right) \left[ 1 - \left( C_d/C_l \right) \cot \varphi \right] \left( \lambda_r \right)^2 d\lambda_r
\]  

(8)

Taking the partial derivative of the part of the integral for \( C_p \) and the derivative is set to equal zero.

\[
\frac{\partial}{\partial \varphi} \left( \sin^2 \varphi \left( \cos \varphi - \lambda_r \sin \varphi \right) \left( \sin \varphi + \lambda_r \cos \varphi \right) \right) = 0
\]  

(9)

The local tip speed ratio, inflow angle, chord length of the blade section can be calculated as the follows:

\[
\lambda_r = \sin \varphi (2 \cos \varphi - 1)/[(1 - \cos \varphi)(2 \cos \varphi + 1)]
\]  

(10)

\[
\varphi = (2/3) \tan^{-1}(1/\lambda_r)
\]  

(11)

where \( \lambda_r \) is the local tip speed ratio, \( c \) is the chord length of the blade section, \( B \) is the number of the blade, \( C_L \) is lift coefficient at the angle of the attack, \( \alpha \) which the angle is at the highest value of the ratio of the lift-drag coefficient.
C. **Qblade Analysis**

Qblade analyses were conducted on the turbine blade in the range of the tip speed ratio, \( \lambda \) from 2.5 to 6.5. In the analyses design velocity of 12 m/s was kept to be constant while the rotation of the rotor was varied with respect to \( \lambda \). As results, the power coefficient and torque values vs. various tip speed ratio graphics were obtained (Fig. 6, Fig. 7).

D. **CFD Analysis**

Numerical simulations for aerodynamic performance of wind turbine were carried out by using Anys-Fluent, which is commercial software for CFD analysis based on the finite volume method. In CFD analysis, SST k-\( \omega \) turbulence module with curvature correction for Reynolds-average Navier-Stokes (RANS) equation was used. Also, second-order upwind discretization in space was used. The convergence rate was monitored during the iteration process by means of the residuals of the dependent variables of the governing differential equations.

Wind turbine module shown in Fig. 8 was obtained using CATIA, commercial software for 3D CAD design.

The external domain, which is a rectangular parallelepiped of width 6 m, length 15 m, height 6 m, is shown in Fig. 9. Domain entrance was defined as “Velocity Inlet” and exit was defined as “Pressure Outlet” boundary conditions. The outer domain's walls were defined as “Symmetry” boundary condition. A cylindrical domain which is connected to external domain was also created around the blades. Moving Reference Model (MRF) was used for this cylinder domain to give blade rotation.
The unstructured grid was applied on the turbine rotating disk area and external flow domain surrounding the turbine. The conformal grid was used on the interface between the rectangular external flow domain and cylindrical rotating disk domain. Different size of grids was used to obtain grid independency of the analysis results. This is achieved by obtaining solutions with increasing number of grid nodes until a stage is reached where the solution exhibits negligible change with further increase in the number of nodes. The grid structure is shown in Fig. 10.

In order to resolve the boundary layer, 25 layers in the boundary were introduced and first layer was located 0.015 mm from the wall. Hence, the first grid point off the wall in the normal direction was placed at a distance less than y⁺=3 from the wall. The y⁺ (ρUf y/μ) is defined as the non-dimensional wall distance for wall-bounded flow in a turbulent boundary layer analysis. To consider the viscous sublayer in the turbulent boundary layer, the value of the y⁺ has to be less than 10 [7, 8].

After the CFD analysis, obtained distribution of the y plus on the blades is shown in Fig 11.

Based on 12 m/s of design wind speed, horizontal axis wind turbine performance analyses were performed by using Ansys-Fluent software. As results, the power coefficient and torque values vs. various tip speed ratio graphics were obtained (Fig. 12, Fig. 13).

**Fig. 9. The Flow domain with 6 m x 6 m x 15 m dimensions for 3D analysis**

**Fig. 10. The grid structure of the flow domain**

**Fig. 11. Contour of y plus distribution on the blades**

**Fig. 12. The power coefficient versus tip speed ratio graphic in Fluent**

**Fig. 13. Torque versus tip speed ratio graphic in Fluent**

### III. CONCLUSION

This study was considered the performance characteristics of the wind turbine, which has SG6043 airfoil. The commercial code Fluent with SST k-ω and the general public license QBlade, which uses BEM theory to predict aerodynamic
coefficients, were used respectively. The following conclusions were drawn:

Xflr5 software was used to obtain the values of the angle where $C_L/C_D$ ratio has maximum and max. $C_L$ at this angle of attack. These values were obtained as 4.50 and 1.22 respectively. Maximum torque value was obtained as 29.937 Nm in Qblade and 25.204 Nm in Fluent at the tip speed ratio of 3.5. Maximum power coefficient value was obtained as 0.457 in Qblade and 0.424 in Fluent at the tip speed ratio 5.5.

The efficiency of the system first increases and reaching to maximum value and then decreases with increasing the tip speed ratio.

There are reasonable agreements between Qblade and Fluent analyses. At high tip speed ratio value, the results get closer in Qblade and Fluent solutions (Fig. 14, Fig. 15).

![Fig. 14. Comparison of torques for wind turbine in Qblade and Fluent analyses](image)

![Fig. 15. Comparison of the power coefficients for wind turbine in Qblade and Fluent analyses](image)

REFERENCES


Wind Speed Modelling Using Inverse Weibull Distribution: A Case Study for Bilecik, Turkey

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Abstract—Wind speed modelling plays a critical role in wind related engineering studies. Frequency distribution of wind speed can be displayed different distributions such as Gamma, lognormal, Rayleigh and Weibull. Weibull distribution is used to model of many regions of the world wind speed in recent year. In this paper, wind speed potential analysis realized using Inverse Weibull Distribution (IWD) for Bilecik, Turkey. Maximum likelihood method for parameter estimation used for wind speed modelling analysis. All analysis is carried out by Matrix Laboratory (MATLAB) programming language. Monthly and yearly wind speeds are modeled by Inverse Weibull distribution. Accuracy of the modelling is evaluated in terms of Root Mean Square Error (RMSE)

Keywords—Wind Speed, Modelling, Weibull Distribution, Renewable Energy, Inverse Weibull Distribution.

I. INTRODUCTION

In modern societies, one of the most important indicators of the economic growth is energy. Energy demand increases continuously due to the rapid population growth and industrialization. This demand cannot be satisfied with the available limited resources. Thus, it is gaining much more importance to benefit from the renewable energy resources in a more effective manner.

One of the renewable energy resources is wind energy. Actually wind energy which is the oldest source has been used since BC 2800 by humankind. Until recent year this energy has been used for water pumping and power generation in rural areas. Today it is used as an alternative source of energy production. Wind energy systems operate depend on wind regime, wind shaft position and size of power generation system [1,2]

The potential of wind energy of a certain region can be determined before a wind conversion system is installed. The determination of wind energy potential depends on accurately modeling wind speed. Statistical properties of the wind speed are important to predict the output energy of a wind conversion system [2]. There are several distribution functions for wind speed and power density analysis in literature. The log-normal distribution [3-6], the inverse Gaussian distribution [7], the wake by [8,9], three-parameter log normal [10], the gamma distribution [11,12], two-parameter gamma distribution [13], hybrid distributions [14-16], the three parameter generalized gamma distribution [17-18], and similar distribution functions were used about energy and other research areas.

Two-parameter Weibull density function [19] is commonly used in wind resource assessment to describe wind speed as a stochastic quantity. There are many different methods for estimating the shape (k) and scale (c) parameters of Weibull wind speed distribution function [19-23].

Alternative distribution which is Inverse Weibull Distribution (IWD) for modelling wind speed data is proposed by Akgül et al [24]. IWD is used for Bursa and Sakarya seasonal wind speed data by them. In this paper, monthly and yearly modeling of wind speed realized using Inverse Weibull distribution and Two Parameter Weibull distribution for Bilecik, Turkey. Maximum likelihood method used for modeling of wind speed. This paper is structured as follows: IWD and Two-parameter Weibull distribution methods are explained by Section 2. Section 3 contains parameter estimation method for IWD. Comparative modeling results are presented in Section 4. Finally, conclusion is given in Section 5.

II. INVERSE WEIBULL DISTRIBUTION

There are different methods for determining the wind speed distributions. In the literature, the two parameters Weibull distribution is often used in the statistical analysis of data. The Weibull distribution function is given by Equation (1).

\[
f_w(v) = \frac{k}{c} \left( \frac{v}{c} \right)^{k-1} e^{-\left( \frac{v}{c} \right)^k}
\]

Where \(f_w(v)\) is the frequency or probability of occurrence of wind speed \(v\), \(c\) is the Weibull scale parameter with unit equals to the wind speed unit and \(k\) is the unitless Weibull shape parameter. The higher value of \(c\) indicates that the wind speed is higher, while the value of \(k\) shows the wind stability.

The cumulative Weibull distribution function \(F_w(v)\) gives the probability of the wind speed exceeding the value \(v\). It is expressed by Equation (2):

\[
F_w(v) = 1 - e^{-\left( \frac{v}{c} \right)^k}
\]

The probability density function and cumulative density function of Inverse Weibull Distribution are given below [24]

\[
f_{IW}(v) = \frac{k}{c} \left( \frac{c}{v} \right)^{k-1} e^{-\left( \frac{c}{v} \right)^k}
\]

\[
F_{IW}(v) = 1 - e^{-\left( \frac{c}{v} \right)^k}
\]
and 
\[ F_W(v) = e^{-\frac{v}{k}} \]  
\( (4) \)

Different scale \((k)\) and shape \((c)\) parameter estimation methods which are Maximum Likelihood Method (MLM), Modified Maximum Likelihood Method (MMLM), Moment Method (MM), Power Density Method (PDM), Graphical Method (GM) and empirical methods are used in literature.

III. MAXIMUM LIKELIHOOD METHOD FOR IWD

The likelihood function for two parameter Weibull distribution is given by
\[ L(k, c) = \prod_{i=1}^{n} f(v_i; \theta) \]
\( (5) \)
\[ L(k, c) = \prod_{i=1}^{n} k c^{-1} v_i^{c-1} \exp(-c^{-1} v_i^c) \]
\( (6) \)

Taking the natural logarithm of likelihood function
\[ \ln L(c, k) = n \ln k - nk \ln c - (k+1) \sum_{i=1}^{n} \ln v_i - c \sum_{i=1}^{n} x_i^{c-1} \]
\( (7) \)

By taking the derivatives of left side the equation with respect to these parameters and equating them zero, the following likelihood equations are obtained
\[ \frac{\partial \ln L(k,c)}{\partial k} = \frac{n}{k} + n c - c \sum_{i=1}^{n} \ln v_i - c \sum_{i=1}^{n} x_i^{c-1} = 0 \]
\( (8) \)
\[ \frac{\partial \ln L(k,c)}{\partial c} = n k - k c^{-1} \sum_{i=1}^{n} v_i^{c-1} = 0 \]
\( (9) \)

These equations are solved Newton-Raphson iterative method by using Matlab (MATrix LABoratory) software in this paper.

IV. WIND SPEED POTENTIAL ANALYSIS

Future and available wind potential is very important to build wind energy conversion system. For this reason estimation parameter results of distribution are studied monthly. Optimum model can be chosen according to performance criteria. The actual data sets collected hourly basis in Bilecik, Turkey, are taken from the Turkish State Meteorological Service. The IW and the Weibull distributions are used to model these data sets.

Fig. 1. Location of selected station and Bilecik province on the map of Turkey

Bilecik is located at N 39° 39’ and E 30° 40’ at the height of 850 m in Turkey as shown in Figure 1.

The maximum likelihood method was used for determining Inverse Weibull and Weibull parameters.

Some descriptive statistics including maximum, mean, standard deviation, skewness and kurtosis of the used wind speed data for selected station is presented Table 1. The coefficient of Kurtosis is very high for Bilecik. It gives the degree of width of peak of a distribution.

In this paper, estimation of monthly and annual parameters for Bilecik region are implemented in Table 2 by using hourly wind speed data for 2014 year.

<table>
<thead>
<tr>
<th>Region</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilecik</td>
<td>12.00</td>
<td>0.2</td>
<td>2.0318</td>
<td>1.1306</td>
<td>1.0800</td>
<td>4.2291</td>
</tr>
</tbody>
</table>

Hourly wind speed recorded by Turkish State Meteorological Service at 10 m height for the period of one years from January 2014 to December 2014.

It can be seen from the Figure 2 that Weibull and Inverse Weibull probability distribution function and cumulative distribution function of sample data .April 2014, are shown

Fig.2. Probability density and cumulative probability density function for sample month for Weibull and Inverse Weibull distribution
Performance criteria of analysis is shown Root Mean Square Error (RMSE) by Equation (10).

\[
RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (y_i - x_i)^2}
\] (10)

Where, \(y_i\) is the actual wind speed probability value, \(x_i\) is the probability value calculated from Weibull distribution and \(n\) is the number of observations.

Table 2 shows monthly wind speed data modeling results which consist of Weibull and Inverse weibull distributions and error values. Error values presented for probability density functions (pdf).

**Table II.**

MONTHLY ANALYSIS RESULTS FOR WEIBULL AND IWD

<table>
<thead>
<tr>
<th>Months</th>
<th>Methods</th>
<th>2014</th>
<th>k</th>
<th>c</th>
<th>RMSE for pdf</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>Weibull</td>
<td>1.1885</td>
<td>2.0545</td>
<td>0.0977</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>1.6473</td>
<td>1.4704</td>
<td>0.0836</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weibull</td>
<td>1.9435</td>
<td>1.8455</td>
<td>0.0981</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>1.6627</td>
<td>1.4806</td>
<td>0.1008</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>Weibull</td>
<td>2.2748</td>
<td>2.1660</td>
<td>0.0692</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>2.0288</td>
<td>1.4890</td>
<td>0.0857</td>
<td></td>
</tr>
<tr>
<td>March</td>
<td>Weibull</td>
<td>2.0241</td>
<td>2.0614</td>
<td>0.0914</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>2.0020</td>
<td>2.0965</td>
<td>0.0977</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>Weibull</td>
<td>1.7354</td>
<td>1.5225</td>
<td>0.0895</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>2.1401</td>
<td>2.3132</td>
<td>0.0690</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>Weibull</td>
<td>2.5904</td>
<td>2.4307</td>
<td>0.0640</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>2.2348</td>
<td>2.5420</td>
<td>0.0737</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weibull</td>
<td>2.1376</td>
<td>1.5341</td>
<td>0.0956</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>2.0935</td>
<td>2.5030</td>
<td>0.0773</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weibull</td>
<td>2.1966</td>
<td>1.5634</td>
<td>0.0945</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>2.1629</td>
<td>2.1439</td>
<td>0.0791</td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>Weibull</td>
<td>2.0498</td>
<td>1.4956</td>
<td>0.0710</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>2.1966</td>
<td>1.5634</td>
<td>0.0945</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weibull</td>
<td>2.2758</td>
<td>1.8371</td>
<td>0.0990</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>1.8458</td>
<td>1.4105</td>
<td>0.0880</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>Weibull</td>
<td>2.1381</td>
<td>1.8864</td>
<td>0.1021</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>1.5017</td>
<td>1.3814</td>
<td>0.0888</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weibull</td>
<td>1.9591</td>
<td>1.7732</td>
<td>0.0925</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>1.0575</td>
<td>1.3276</td>
<td>0.1248</td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>Weibull</td>
<td>2.0466</td>
<td>2.1061</td>
<td>0.0595</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IWD</td>
<td>1.5048</td>
<td>2.3537</td>
<td>0.0770</td>
<td></td>
</tr>
</tbody>
</table>

IWD results for some months are better than Weibull distribution. Especially, left side of the probability density function is good fit to IWD. In other words, good results are observed for low wind speed data in IWD (Figure 3).

Fig.3. Comparison of low wind speed data

**V. CONCLUSIONS**

The potential of wind energy of a certain region can be determined before a wind conversion system is installed. The determination of wind energy potential depends on accurately modeling wind speed. Statistical properties of the wind speed are important to predict the output energy of a wind conversion system. There are several distribution functions for wind speed and power density analysis in literature.

In this paper Inverse Weibull Distribution which is proposed for wind speed data by Akgül et al. and Two-parameter Weibull Distrubition function are used for actual hourly wind speed data for Bilecik, Turkey. Although Akgül et al. modelled for seasonal wind speed data, monthly analysis are used for IWD in this paper.

IWD results are better than Weibull distribution function for low wind speed data modelling. These analysis are preliminary research for wind speed data.

In future studies, we will apply this method for seasonal analysis which has lots of years and different parameter estimation methods.
ACKNOWLEDGMENT

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REFERENCES


A Survey on Learning System Applications in Energy System Modeling and Prediction

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Abstract— Learning Systems (LS) such as machine learning, statistical pattern recognition and neural networks are computer programs that can learn from sample data and develop a prediction model that makes prediction for new cases. The most important think related with a prediction model is to achieve results as closer as to real situation while making predictions. This is important because being closer to real results help to reduce the costs of feasibility studies in system installation. The performance of Learning Systems has been raised in latest years such as it sometimes exceeds the performance of humans. That’s why the applications of Learning Systems have been increased in many areas. This paper reviews the present applications of Learning Systems in energy system modeling and prediction especially in renewable energy systems such as wind and solar. The aim of this paper is to create a vision for researchers by gathering the present applications and outline their merits and limits and the prediction of their future performance on specific applications.

Keywords— Energy efficiency, Source installation, Estimation, Artificial intelligence

I. INTRODUCTION

Learning Systems (LS) are research areas of computer science that are used to extract information from large data stores [1, 2]. It includes concepts such as machine learning, statistical pattern recognition and neural networks. In everyday life in many areas such as education, health, telecommunication, transportation, marketing, meteorology, earth sciences and etc. a large quantity of data have been collected. Due to the growth in these data, extracting valuable information from large data stores has become an engineering discipline. This valuable information than is used for developing prediction models that can learn from sample data and develop a prediction model that makes prediction for new cases [3-5]. The objective of this paper is to gather and argue the studies that are related to Learning System techniques in modeling and prediction for renewable energy systems. The following of the paper is organized as follows: In the second part the learning system is explained briefly. While wind energy applications of learning system are given in the third part, solar energy applications are given in the fourth part. Finally conclusion is given.

II. LEARNING SYSTEMS

Learning systems are the computer programs that can learn from the sample data and can predict for the future [1, 2]. While there are many learning system methods and applications in the literature, this paper is focused on the presentation of some of the learning system applications on energy system modeling and prediction. Since energy sources are not abundant predictions for appropriate and satisfactory use of these energy sources are essential. Some of the most common methods of learning systems, used in the field of energy system modeling and prediction, are linear regression, artificial neural networks (ANN), support vector machine (SVM), decision trees and etc. [6]. In the literature many studies can be found related to the solar irradiation, wind speed, production of energy from wind and solar and reducing the operating costs with the realization of economic dispatch [7]. In design of wind farms, solar plants and power generators, wind and solar characteristics such as distribution of wind speeds and solar irradiation of the location have to be known. As this information is not always available Learning System algorithms are used to predict this information according to the historical data.

Learning System algorithms are the samples of supervised classification algorithms. A supervised classification algorithm uses a database which includes attributes and the class information. The sample of a database, which is given in Table1, has \( m \) data that each one has \( n \) attributes, called as predictors, and class information, called as target.

A supervised classification includes two steps which are the training and the testing steps. First of all the database is split into two parts according to some criterion. First part of the database, training set, is used in the training step and the second part, test set is used in the testing step. In the training step, a model is constructed by using the training set of which the class information is known.
TABLE I
A SAMPLE DATABASE

<table>
<thead>
<tr>
<th>Case ID</th>
<th>Attributes (Predictors)</th>
<th>Class information (Target)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X₁, X₂, ..., Xₙ</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Than using the test set the performance of the constructed classification model is evaluated. Once the model is constructed, a sample data with its known attributes and unknown class information can be classified into a class. In the following part some of the popular Learning System algorithms that are used in renewable energy systems are explained briefly.

A. Linear Regression

Linear regression model is a very popular mathematical classification model that is used for making predictions, and has many applications in various fields including sciences such as social sciences and physical sciences [8]. In the regression analysis it is used a database that is based on observed data over a period of time. In this database attributes would be the predictors and the class information would be the target (Table1). As this is a supervised classification model, it has a training step in which the database, which’s target values are known is used and a regression model is constructed. Than the model is tested using the part of the database that is not used for the training process. At the end, once the model is constructed it can be used to predict the target value of a case which’s target value is unknown.

Basically a linear regression model explains the relationship between the predictor and the target with a straight line. In some applications there is only one predictor but in some applications it could be more than one predictor, multivariate linear regression analysis [8]. The single predictor linear regression model can be expressed as in Eq.1 and the 2-Dimensional graphical representation is given in Fig.1.

\[ y = ax + b + \epsilon \]  

(1)

In Eq.1 the regression parameters a and b are the angle between a data point and the regression line, and the point where x crosses the y axis (x=0) respectively [9].

In multivariate linear regression analysis the regression equation has a form as given in Eq.2.

\[ y = b + ax_1 + cx_2 + \cdots + ex_{n-1} + \epsilon \]  

(2)

B. Artificial Neural Networks (ANN)

Artificial Neural Networks is a supervised learning algorithm which bases the working principle of human brain. It learns from data samples, and then develops a model which can learn from these data samples and can make predictions for the future. It consists of basically two layers that are called the input layer and the output layer. Each layer has different numbers of neurons which are associated with the neurons in the other layer with a weight. Working principle of an ANN is given in Fig 2. The output of the network is the application of the sum of the weighted inputs to an activation function.

There are some advantages of ANN compared to the conventional algorithms such as the speed, the simplicity, the capacity of the network to learn from examples and the realistic results due to the use of actual data for the training step of the network [10].

C. SVM

Support Vector Machine (SVM) is a tool for solving pattern recognition problems and it is based on the concept of finding the decision planes that define decision boundaries, and can separate a set of objects belonging to different classes (Fig.3.) In Fig 3.a a schematic example of a linear classifier can be seen. But however in most real classification problems, data points, belong to different classes, cannot be distinguished from each other linearly (Fig.3.b). Classification tasks given in Fig.3.b, are known as hyper plane classifiers and SVMs are particularly suited to handle such tasks. In other words with hyper plane classifiers, the data can be mapped into a
higher dimensional feature space, and an optimal separating hyper plane can be constructed in this new space [11-13] (Fig.4).

Fig. 3 A schematic example of a) A linear classifier, b) A nonlinear classifier [14]

![Input space Feature space](image)

Fig. 4 The basic of a SVM classifier [14]

SVM algorithm can cope with high dimensional data well although when the training samples are relatively small [15]. In the literature SVM algorithm is used for medium and long term wind speed predictions [16-18], and a few studies can be found in which SVM is used for short-term wind speed prediction [19].

III. WIND ENERGY APPLICATIONS

Wind speed predictions are performed for three different time scales such as short, medium and long terms. While the time intervals in short term are about 10 sec or 10 min [20-22] they become hourly predictions for medium term [23-25] and involve days for long term predictions [26-28]. Each time scale is indicative of different things. For example short term wind speed prediction is important to control of wind turbines, medium term supports unit commitment planning and the long term is used in determining generation mix and scheduled maintenance of power systems [29]. Wind speed prediction methods can be grouped into four categories such as statistical, physical-based, data mining and hybrid methods [30]. When the wind characteristics are examined, it can be seen that it has both linear and nonlinear characteristics that can be analyzed with the learning systems such as data mining methods that can model both the linearity and the nonlinearity of wind speed [30].

The frequently used data mining algorithms in wind speed prediction are tree-based regression algorithms [31-34], k-nearest neighbor [35], support vector machine (SVM) [36-37], Artificial Neural Networks [38-40] and ensemble data mining algorithms [41]. Among these prediction models prominent ones are developed from ANN and SVM algorithms [30]. The ANN wind speed prediction model is applied for short [20, 42-44] and the long term predictions [42]. The data mining models may suffer from the limited data in terms of accuracy [45]. The long term approaches of ANN model can be seen as monthly in [46] and as monthly and daily in [47]. ANN model has some advantages according to the conventional algorithms such that the speed, the simplicity and the capacity of the network to learn from examples. [48].

In [23] ANN is used for wind speed prediction that is the mean monthly wind speeds prediction in Cyprus where any data is not available. In [49] it is proposed multivariate time series models to predict the power ramp rates of a wind farm of 100 turbines for a time horizon of 10-60 min. In the study, the power changes are predicted at 10 min intervals and five data mining algorithms are used to build the model. These are multilayer perceptron algorithm (MLP), the support vector machine (SVM) regression, the random forest, the classification and regression (C&R) tree and pace regression algorithm. According to the results of the study, the SVM regression algorithm outperforms the rest of the four algorithms. In [19] a least-squares SVM (LS_SVM) approach is applied for wind speed prediction. In the paper it is presented a systematic study on fine tuning of LS_SVM model parameters for one-step ahead wind speed forecasting. In the study they applied three different SVM kernels that are linear, Gaussian and polynomial kernels. Training sample size, SVM order, kernel parameters and regularization parameter are used as the SVM parameters. According to the obtained results LS-SVM performance is closely related to the dynamic characteristics of wind speed, performance of the model is closely related to the parameters comparable results are obtained for the three of the kernels under optimal combination of parameters after fine tuning and finally when the training sample size or SVM order is small the linear kernel gives the worse performance. In [50] they integrated data mining and evolutionary computations to monitor wind farm power output. In the study five different data mining algorithms are compared. These algorithms are multi layer perceptron (MLP), REP tree, M5P tree, bagging tree and the k-nearest neighbor (k-NN) algorithm. According to the results the best prediction results are obtained from the k-NN model combined with the principal component analysis approach. In order to obtain good performance from this model, the conditions of the wind farm has to be normal otherwise its performance is poor. In [51] they used learning systems algorithms to analyze time series models for predicting the power of a wind farm for 10-min and hour-long intervals. As in [50] the model is built using the same five data mining algorithms. The results showed that SVM regression algorithm gives the best predictions of wind power and wind speed at 10-min intervals up to 1 h into the future. The MLP gives the best predictions over hour-long intervals up to 4 h ahead. As it is reported in the study wind speed predictions are poor.

IV. SOLAR ENERGY APPLICATIONS

In the literature in various fields of renewable energy systems it can be found many modeling and prediction applications of ANN. In [52] two different application of ANN can be seen. The two of these applications are for to determine the collector optical efficiency which is a very
important parameter as it is used to determine the overall effectiveness of solar concentrating collectors. In the first application to determine the collector optical efficiency ANN is used for the estimation of collector intercept factor and in the second one it is used to estimate the radiation profile on the receiver of collector.

In [48] an extended version of the study given in [52] can be found. In [48] ANN is also used for solar water heating systems besides the modeling of a solar steam generator. According to the results ANN can be successfully used in the estimation of the system energy extraction and the stored water temperature rise [53].

In [10] a study is performed that gives an overview using Artificial Intelligence (AI) techniques for sizing photovoltaic (PV) systems. The Artificial techniques included in the paper are Artificial Neural Networks (ANN), fuzzy logic, genetic algorithm, wavelet and the hybrid systems that are fuzzy neural networks, genetic algorithms and neural networks, wavelet and neural networks, genetic algorithms and fuzzy logic. In the paper included applications of AI techniques are as follows: Neural networks for sizing stand-alone PV systems; genetic algorithms for sizing hybrid PV system; genetic algorithms for sizing grid-connected PV-system; genetic algorithms for sizing hydrogen PV system; neural networks, neuro-fuzzy and genetic algorithm for sizing stand-alone PV systems and neuro-fuzzy and wavelet for sizing PV systems. According to the overview in [10] the use of AI techniques for sizing PV systems has the advantage that it provides good optimization, especially in isolated areas, where the weather data are not always available. In [54] they argue the solar forecasting methodologies and also the solar resource and power output of solar plants applications. As learning system algorithms, they examine the ANN and k-NN algorithms. In [55] they performed a prediction model for solar power generation from weather forecasts using linear least squares and SVM using multiple kernel functions. According to the results they showed that SVM-based models are 27% more accurate than existing forecast-based models.

V. CONCLUSIONS
The Learning Systems (LS) are computer programs which learn from sample data and develop a prediction model makes prediction for new cases. The performance and accordingly the application of Learning Systems have been raised in the last years. This paper reviews some of the present applications of Learning Systems in energy system modeling and prediction especially in renewable energy systems such as wind and solar. As the learning systems linear regression, ANN and SVM are considered. It is aimed with this study to create a vision for researchers by gathering the present applications and outline their merits and limits and the prediction of their future performance on specific applications.

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[9] https://docs.oracle.com/cd/B28359_01/datamine.111i/b28129/regress.ht
m/CHHHHHB
Numerical simulation of a single PEM fuel cell with double-serpentine flow channel

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Abstract—In this study, a 3-dimensional, single-phase model has been established to investigate the performance of proton exchange membrane (PEM) fuel cells with double-channel serpentine flow fields. The single PEM fuel cell has a 13x73 mm² active layer. The complete set of conservation equations, mass, momentum, energy, species and charge were taken into account and solved using the commercial computational fluid dynamics (CFD) software ANSYS Fluent® 16.2 with Gambit® (2.4.6) as a pre-processor. Two flow patterns including co-flow and counter flow were considered for all flows in the cell. The model was used to investigate the performance of fuel cell by determining the current density, oxygen and hydrogen mass fraction distributions. The simulation results were illustrated polarization curves including I–V and I–P curves. As a result the co-flow model is more accurate and has higher current density than the co-flow model. It is also noted that the optimal oxygen consumption of the channels was achieved at 0.6 V value obtained the maximum current and power density to improve the performance of fuel cell. Also the performance of the PEM fuel cell can be improved by increasing the reactant gases humidification. But increasing the humidity of the cathode at low cell voltage will lead to decrease performance.

Keywords—PEM fuel cell, current density, humidification, performance

I. INTRODUCTION

Fuel cell is an electrochemical device that continuously changes the chemical energy of a fuel (hydrogen) and oxidant (oxygen or air) directly to electrical energy and heat, without combustion. The proton exchange membrane fuel cell (PEMFC) is considered to be a promising power source, especially for transportation and stationary cogeneration applications due to its high efficiency, low operating temperature, high power density, low emission and low noise.

In reference [1], it was studied time-dependent measurements of pressure drop in different flow fields on the cathode of a PEM fuel cell with different operating conditions. Their results showed that the interdigitated flow channel has the biggest pressure drop among the other flow field channel configurations.

Other working groups observed that channel geometry and surface property both have appreciable effects on the volume of accumulated water. Also it was resulted that the water droplets were larger and dispersed individually in the direction of flow in the rectangular channels with serpentine flow fields. And the channels with triangular geometry retained less water than rectangular channels of the same cross-sectional area, and the water was mostly trapped in the two corners adjacent togas the diffusion media. [2]

Based on the work of [3] it was solved for three different flow channel geometries: 4-step serpentine, parallel and pin-type high temperature polyelectrolyte membrane fuel cell (HTPEMFC) by using Computational Fluid Dynamics (CFD). Their results showed that serpentine and pin-type flow channels were found to perform very similarly. Also better fuel cell performance was predicted while temperature grows as it could be expected.

In their work, Cheng et al. presented in [4] that following results: Increasing the relative humidity enhances the membrane ion conductivity, which favours the current density output. On the other hand, reducing the mass fraction of oxygen gas at entrance plane with high relative humidity diminishes the fuel cell performance as the relative humidity of the cathode gas increases. At low current densities, an increase of relative humidity causes the water vapour concentration in the catalyst layer to reach the saturation level, reducing the occurrence of ohmic polarization.

Various operating factors, such as mole fractions of species, pressure distribution, overpotential, and inlet relative humidity, affect the performance of proton exchange membrane fuel cells (PEMFCS) [5]. Specifically, the land ratio of the gas channel and rib is an important parameter affecting PEMFC performance because current density distribution is influenced by this geometrical characteristic. Yang et al. investigated geometrical shape and relative humidity in their study. A three-dimensional numerical PEMFC model was developed to illustrate the current density distribution as the determining factor for PEMFC performance.

In reference [6], the effects of operation conditions on the performance of a polymer electrolyte membrane fuel cell with 25cm² active area were investigated experimentally. It was found that the performance of fuel cell performance can be enhanced by increasing the RH and temperature of the inlet gases and the operating temperature.

Takalloo et al. in reference [7] investigated the impact of alteration in humidification and inlet flow rates on performance improvements for PEMFC both experimentally and numerically. One of their results is that anode side needs
more humidity for preventing the membrane from drought and the cathode side needs less humidity because of producing water and avoiding from flooding.

In this study, it was investigated a 3-D, isothermal, single-phase, steady-state model with double serpentine flow channel configuration of a PEM fuel cell by using ANSYS-Fluent based on computational fluid dynamic technique.

II. NUMERICAL MODELLING

In this study, the model presented is a three-dimensional, isothermal, single-phase, steady-state model that resolves coupled transport processes in membrane, catalyst layers, gas diffusion layers and reactant flow channels of a PEM fuel cell (Fig.1). The number of elements in the computational domain field is 30439 elements. General geometrical property of the PEM fuel cells components are given at Table I.

A. Description of Model

The geometric model is created in Gambit 2.4.6. ANSYS-Fluent 16.2 PEMFC module is used in this research to compile the appropriate user-defined functions for a PEMFC. In this model, the numerical domain is a single-cell geometry domain. Pure hydrogen and air are used as reactant gases in the model. The inlet flow velocity was controlled by stoichiometry numbers of 2 at the anode and 2 at the cathode. The operating pressure was 200 kPa absolute at the exit of the cell. The active surface area is 13x73 mm², with double-serpentine flow field configuration. The channels are 1 mm in width and 1 mm in depth. The width of the rib is 1 mm. (Fig. 2)

B. Theoretical Formulation

Basic equations used during fuel cell operation are as follows:

Conservation of mass equation:
\[ \nabla (\rho \mathbf{u}) = S_m \] (1)

The source terms are;
\[ S_m = S_{H_2} + S_{W_{el}} + S_{w_{lp}} + S_{aw_{w_{e}}} \] (2)
\[ S_m = S_{O_2} + S_{w_{el}} + S_{w_{lp}} + S_{c_{w_{e}}} \] (3)

\[ S_{H_2} = - \frac{M_{H_2} A_{cel}}{2F} \] (4)
\[ S_{O_2} = - \frac{M_{O_2} A_{cel}}{4F} \] (5)

Momentum transport equation:
\[ \nabla (\rho \mathbf{u} \mathbf{u}) = -\nabla P + \nabla \cdot (\mu \nabla \mathbf{u}) + S_{p,i} \] (6)

Here \( \beta \) is the permeability, \( S_{p,i} \) is the sink source term for porous media in x, y and z-directions;
\[ S_{p,i} = - \left( \sum_{j=1}^{3} \frac{1}{E_j} \mu u_j \right) \] (7)

Species transport equation:
\[ \nabla (\rho m_i \mathbf{u}) = \nabla (J_m) + S_z \] (8)
Here \( n \) denotes for \( H_2, O_2 \) water vapor and liquid water. The source terms are the same as those of the conservation of mass equation. The diffusion mass flux (\( J \)) of species \( n \) in \( x \)-direction is:

\[
J_{x,n} = -\rho D_{x,n} \frac{\partial m_{x,n}}{\partial x}
\]  

(9)

Energy equation:

\[
\nabla (\rho u h) = \nabla (k \nabla T) + S_h
\]  

(10)

The source term \( S_h \) can be obtained by energy losses and heat source by phase change. The heat source from the electrochemical reaction:

\[
S_{he} = h_{ran} \left[ \frac{I_{cell}}{2F} \right] - IV_{cell}A_{cv}
\]  

(11)

The local current density of the cell is calculated from the open circuit voltage (\( V_{oc} \)) and the losses:

\[
I = \frac{\eta}{t} \left(V_{oc} - V_{cell} - \eta\right)
\]  

(12)

where \( t \) is the membrane thickness and \( \sigma_m \) is the membrane conductivity and defined as:

\[
\sigma_m = \left( 0.51 \frac{m_{m, dry}}{m_{m, dry}} C_{wa} - 0.326 \right) \exp \left( 1268 \left( \frac{1}{T_0} - \frac{1}{T} \right) \right)
\]  

(13)

C. Computational Method

The solution strategy was based on the SIMPLE algorithm. Momentum equations were solved for the velocity followed by solving the equation of continuity, which updates the pressure and the flow rate. A HP-PC-Intel® Xeon® CPU E5-2650v2@2.6 GHz, 2.6 GHz, 64 GB was used to solve the set of equations. The computational time for solving the set of equations was about 3 min.

Boundary conditions are set as follows: constant mass flow rate at the channel inlet (mass flow inlet type) and constant pressure condition at the channel outlet (pressure outlet type). The membrane-GDL interface was defined as a wall. The anode voltage was grounded (\( V = 0 \)) and the cathode voltage was adjusted 0.9V, 0.8V, 0.7V, 0.6V, 0.5V, 0.4V respectively less than the open-circuit potential (0.95 V). The current density values which correspond to each voltage value in the simulation results were noted. Both anode and cathode terminals were assigned wall boundaries. Hydrogen and air velocities are evaluated from the chemical stoichiometric ratio, operational pressure and temperature by the following equations:

\[
u_{a,in} = \frac{I_{ref}}{n_e F A_{MEA}} \frac{1}{X_{H_2,in}} \frac{R T_{in,cell}}{P_{a,in}} \frac{1}{A_{ch}}
\]

\[
u_{c,in} = \frac{I_{ref}}{n_e F A_{MEA}} \frac{1}{X_{O_2,in}} \frac{R T_{in,cell}}{P_{c,in}} \frac{1}{A_{ch}}
\]

(14)

(15)

Where \( I_{ref} \) is the reference current density, \( F \) is the Faraday constant, \( n_e \) is number of electrons transferred which equals 2 for the anode flow side and 4 for the cathode side.

Both the anode and cathode side exit boundary conditions are selected as pressure outlet, inlet conditions are selected as mass flow inlet type conditions. The operational temperature is 343 K for the anode and cathode side. Physical and electrochemical properties of the PEM fuel cells are given at Table II.

### Table II

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas diffusion layer porosity</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Gas diffusion layer viscous resistance</td>
<td>1/m²</td>
<td>1e+12</td>
</tr>
<tr>
<td>Catalyst layer porosity</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Catalyst layer viscous resistance</td>
<td>1/m²</td>
<td>1e+12</td>
</tr>
<tr>
<td>Catalyst layer surface/volume ratio</td>
<td>1/m²</td>
<td>200000</td>
</tr>
<tr>
<td>Reference H₂ diffusion</td>
<td>m/s</td>
<td>3e-05</td>
</tr>
<tr>
<td>Reference O₂ diffusion</td>
<td>m/s</td>
<td>3e-05</td>
</tr>
<tr>
<td>Anode reference exchange current density</td>
<td>A/m²</td>
<td>7500</td>
</tr>
<tr>
<td>Cathode reference exchange current density</td>
<td>A/m²</td>
<td>20</td>
</tr>
<tr>
<td>Electrolyte area</td>
<td>m²</td>
<td>0.000949</td>
</tr>
<tr>
<td>Open circuit voltage</td>
<td>V</td>
<td>0.95</td>
</tr>
<tr>
<td>Operation pressure</td>
<td>kPa</td>
<td>200</td>
</tr>
<tr>
<td>Operation temperature</td>
<td>K</td>
<td>343</td>
</tr>
<tr>
<td>Cathode mass flow rate</td>
<td>kg/s</td>
<td>calculated</td>
</tr>
<tr>
<td>Anode mass flow rate</td>
<td>kg/s</td>
<td>calculated</td>
</tr>
</tbody>
</table>

III. RESULTS AND DISCUSSIONS

A. Effects of Direction of The Reactant Gases on Current Density

Fig. 3 Contours of current density distribution (A/m²) in the middle of model at x-y plane, 0.6 V (a) counter flow, (b) co-flow

Fig. 3(a) and 3(b) shows the counters of current density distribution at x-y plane in the middle of the model for co-
flow and counter flow channels at the value of 0.6 V. It can be seen from the Fig. 3 that the counter flow channel model has better current density distribution than co-flow channel model. The reason of obtaining higher local current density in counter flow channels is that inlets and outlets providing for an increasing mass transfer.

![Graph 1](image1.png)

Fig. 4 I–V and I–P curves of the model with co-flow and counter flow at 100% relative humidity

In Fig. 4, 5 and 6 compare the highest and lowest performance polarization and power density curves respectively of different humidification conditions for both co-flow and counter flow channels. Similar to the performance curves presented in Fig. 4, 5 and 6 for the double serpentine pem fuel cell, varying the relative humidity, counter flow channel model has better performance results than co-flow channel model.

![Graph 2](image2.png)

Fig. 5 I–V and I–P curves of the model with co-flow and counter flow at 50% relative humidity

Fig. 5 displays polarization curves that produced similar performance results (within a voltage value of 0.6V) for 50% relative humidity both types of channels.

![Graph 3](image3.png)

Fig. 6 I–V and I–P curves of the model with co-flow and counter flow at 10% relative humidity

As shown in Fig. 6, decreasing the relative humidity of anode has a similar effect as higher performance of counter flow for the 100% anode humidification value, and is most notable at low cell voltage value, particularly after 0.5 V. Although maximum power density was approximately reached at 0.4V cell voltage value with this relative humidity condition.

Fig. 4 shows that it was reached at 0.6V and 100% relative humidity. As a result of them, decreasing the relative humidity from 100% to 10% has caused serious decline of 66.6 percent of cell performance.

### B. Effect of Humidity of Reactant Gases

1) **Anode Humidification**: In order to reach good cell performance, there must be water balance between anode and cathode. When hydrogen at the anode inlet is fully humidified, the humidity of the membrane can be well maintained. However if hydrogen is insufficiently humidified, membrane dehydration could occur on the anode side. The problem of water deficiency on the anode side of the membrane can be solved by humidification of hydrogen flow at anode side. For each of the gas humidification configurations for the double-serpentine PEMFC model, it was investigated the water accumulation in the membrane operated with constant operating conditions. In Fig. 7 it is shown that I–V and I–P curves cathode RH= 10% and anode RH =10%, 50%, 100% respectively. According to the simulated results in Fig.7, as anode relative humidity increase, the overall water uptake in the system increases. This increase enhances the cell performance. Maximum power density was reached at 0.7 V, 0.9258 A/cm² with the value of 0.6481W/cm².
Contours of current density distribution (A/m²) in the middle of model with different relative humidity at x-y plane, 0.6V is shown at the Fig. 8. From Fig. 8(a), Fig. 8(b) and Fig. 8(c), it can be seen that the current density increases while the relative humidity of hydrogen increases.

2) Cathode Humidification: The membrane is sufficiently hydrated by taking in water available from the fully humidified hydrogen. In Fig. 10 it is shown that I–V and I–P curves anode RH = 100% and cathode RH = 10%, 50%, 100% respectively. However, it is clearly seen from the figure that the current density is increased by the decreasing cathode relative humidity at low cell voltage. But, the cell performance increases with increasing relative humidity of oxygen at low current densities and high cell voltage. According to the results obtained below; cathode humidification was found not to be as important as the anode humidification.

C. Effect of Cell Voltage on Oxygen Concentration

It can be seen in Fig. 11 the molar concentration of O₂ at cathode channel increases with increasing the cell voltage. But Fig. 11 displays clearly that a reduction between input and output of the cell at the low voltage value has occurred while it is not seen a significant change of the gas concentration at high voltage.
maximum current and power density

As mentioned above, the reason for this decrease is that diffusing the oxygen from channel through the GDL in order to occur the electrochemical reaction. As shown in the Fig. 11(b), it is also noted that the optimal oxygen consumption of the channels was achieved at 0.6 voltage value obtained the maximum current and power density to improve the performance of fuel cell.

IV. CONCLUSIONS

A three-dimensional computational fluid dynamics model of a PEM fuel cell with double serpentine flow channels was developed to investigate the effects of flow direction, cell voltage and reactant gases humidification on performance. Using a single-phase, steady-state, three-dimensional model of PEM fuel cell, the following conclusion was obtained; the humidity in the reactant gases is an important factor to consider for improving the cell performance. As the relative humidity of anode side increases, both the chemical reaction and mass transfer of hydrogen are enhanced due to the increase of water content in the membrane, which leads to a better cell performance. It was observed that excessive humidification of the cathode caused to decrease the performance. By using low humidification condition of cathode side, the oxygen concentration in the reactants increases and the water vapour concentration on the cathode side decreases, this reduces cathode flooding and improves the cell performance. Because of that providing for an increasing mass transfer between inlet and outlet, optimum power density value was reached at counter flow channel PEM fuel cell. The maximum power density for the highest performing was 0.6481 W/cm² and occurred at 100%/10% anode/cathode humidification with counter flow channel.

REFERENCES

Monthly Optimization of a New Hybrid Renewable Energy System Considering Energy and Agricultural Efficiency

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Abstract—Clean and cheap energy in agriculture play a key role in improving agricultural productivity, environmental sustainability, and economic performance. This paper presents the result of the monthly optimization analysis for enhancing energy efficiency and conservation in a new hybrid system based on solar and wind energy potentials by reason of its climatic and regional factors. Using the data for one year, a preliminary study has been carried out for the selected station which produced important information for an extended work. The monthly optimization analysis results have been determined by using earth observation data of solar and wind which are registered in this region. According to the wind and solar data, the optimum month was found as July considering energy and agricultural efficiency. Results can be used either to increase the performance of the new hybrid system or to analyze long-term agricultural and energy studies with more efficiently.

Keywords—Hybrid Renewable Energy System, Optimal Energy Production.

I. INTRODUCTION

Energy is one of the biggest requirements for humanity since the first ages. In the modern age, energy has been indispensable for us in houses, agricultural regions, industrial regions, public utilities and outdoors with different needs. Most of these energy demands are met from fossil sources [1-3]. Fossil sources have been decreasing and for that reason more pollution has occurred day by day. Therefore, new energy sources are necessary to meet the energy needs [4, 5]. It is known that the renewable energy resources like as sun, wind, hydro, biomass and geothermal should be evaluated for the future of our world in view of the environmental effects such as global warming, climate change, and carbon emission. They come to mind first between clean energy resources, the sun has the biggest energy potential among them. Researchers are under way of progress in by forming this huge potential for the benefit of humanity like solar PV technology [6-8]. Wind energy is also other one of the most promising renewable power generation technologies nearly as large as solar energy potentials and also it is, used widely as a cheap source of energy for local energy requirements in all over the world. The capacity of modern wind turbines generated in recent years is quite high [9,10].

It is difficult to provide uninterrupted power with the solar and the wind renewable energy sources alone because these kinds of systems are dependent on the weather conditions. The design of hybrid systems is the necessary in order to ensure uninterrupted energy from these systems [11]. Since different renewable energy sources can implement to each other, multi-source hybrid alternative energy systems provide higher quality and quality power to people than a system based on a single resource. The thought of taking advantage of the hybrid renewable energy systems come the first and foremost when taken together with the environmental and economic impacts in today's conditions [12-14].

In the hybrid system studies, system components are usually installed to detached and large areas. In this case, it causes to gradually decrease in agricultural lands and limits the application of renewable energy systems. With this study, a new hybrid renewable energy system was designed. All system components are collected on a greenhouse enable to using agricultural land. In addition, optimum energy production was determined according to working performance of the system on a monthly basis.

II. MATERIAL AND METHOD

This study focuses on, environment-friendly energy deposition, an effective usage of agricultural land and obtaining maximum energy per unit area. All components of this new system are illustrated in Figure 1.

![Fig. 1 Schematic representation of New Hybrid Systems](image-url)
A. System Components

1) Photovoltaic System (PV): Photovoltaic solar panels generate electricity energy from solar radiation directly [15]. In this study, Si-poly module was selected according to the reasonable price and performance properties that are the important factor for selection of panel [16]. Totally 450 panels, which are specified during the design of panels connected in series. These panels are located on the greenhouse which has 20x50 m² area. Monthly output power performances of the selected photovoltaic system are given in Figure 2.

2) Wind Turbine System (WT): Wind turbines firstly convert the kinetic energy of the wind to the mechanical energy and then electrical energy [17]. The selected wind turbine has 34 m rotor diameter, its stepping area of horizontal axis 904 m and it has maximum 250 kW output power [18]. In addition, the wind turbine was selected according to wind data of Karaman province and horizontal axis wind turbine that works at least %45 efficiency [10]. Monthly output power performances of selected wind turbine are given in Figure 3.

3) Pumped Hydroelectric Power Station System (PHS): Pumped hydroelectric power station system is a clean energy deposition method which has an upper-bottom reservoir and mechanical parts. It enables to deposition of energy on water, and works without any chemicals. There are lots of studies about pumped hydroelectric systems [19-23]. With this new system design, it is aimed to store excess energy via PHS system for use when there is no power production is provided. This PHS system with 92 kW total instantaneous powers was designed. Pelton turbine was selected according to capacity and physical properties of the system.

4) Light Transmission System: In the designed hybrid system, photovoltaic panels were located on the top of the greenhouse that is application area of the system. But they block the light transmission in the greenhouse. An efficient light transmission system which is located on shading distance of photovoltaic panels light transmission in the greenhouse is provided when the plants need at certain times. In this way, sufficient light transmission in the greenhouse is provided. The light transmission system is given in Figure 4.
5) **Plant-House**: Greenhouses protect of plants and provide increasing of their yield and quality by keeping the indoor temperature in appropriate circumstances. The existing agricultural fields will be brought to the more efficient state thanks to greenhouse without being affected by seasonal differences. These systems have been used for a long time in the world and in our country. In this proposed new system a greenhouse with 20x50 m² area was selected.

### III. RESEARCH RESULTS AND COST ANALYSIS

In this study, electric production for new designed hybrid renewable energy system was calculated. Annual solar radiation, wind and temperature data for Karaman was used for calculations. The maximum electric production was observed in July by data on a monthly base. In addition cost analysis of the new designed system is detailed in Table 1. As a result of the installation of the system and calculation of the total investment payback period was calculated as 4.09 years.

#### TABLE I

<table>
<thead>
<tr>
<th>System Components</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV Systems</td>
<td>Daylight was distributed uniformly in the greenhouse, and electric energy was obtained.</td>
</tr>
<tr>
<td>Light System</td>
<td>Electric energy was obtained</td>
</tr>
<tr>
<td>WT</td>
<td>Greenhouse is cheaper, regular and heating was provided with a constant temperature.</td>
</tr>
<tr>
<td>PHS</td>
<td></td>
</tr>
<tr>
<td>Yield (%15-17)</td>
<td></td>
</tr>
<tr>
<td>Number (450)</td>
<td></td>
</tr>
<tr>
<td>Generated Power (117 kWh)</td>
<td></td>
</tr>
<tr>
<td>Investment Amount (90000 $)</td>
<td></td>
</tr>
<tr>
<td>Maintenance and Repair expenses</td>
<td></td>
</tr>
<tr>
<td>Generated Electricity (256736 kWh/year)</td>
<td></td>
</tr>
<tr>
<td>Payback Period (4.09 years)</td>
<td></td>
</tr>
</tbody>
</table>

![Fig. 4 Schematic representation of the light transmission system](image)

In this study, a new hybrid renewable energy system was designed for the nature-friendly electric production without harming to agricultural lands. The performance of the designed system has been examined separately for each month of the year using one-year data of Karaman. The best electric production performance for this system has been determined in July. In addition, the total payback period was calculated as 4.09 years. According to research results, it is predicted that this new system is practicable for Karaman due to its geographical and climatic features. As a result, the proposed new system will support the expansion of the use of renewable energy systems that will be built in the future, because it provides high output power and high performance from the field of agricultural production, as well as being nature-friendly.

### IV. CONCLUSIONS

The authors would like to thank Turkish State Meteorological Service (TSMS), for providing us with measured data and Authors would like to express their gratitude to Karamanoglu Mehmetbey University for financial support.

### ACKNOWLEDGMENT

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### REFERENCES


Laminar Natural Convection in Triangular Enclosures

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Abstract— Natural convection in non-rectangular enclosures is numerically analyzed in this study. Streamlines and isotherms are presented for different triangular enclosures with different boundary conditions and Rayleigh numbers.

Keywords— Natural convection, laminar flow, Nusselt number, Rayleigh number, triangular enclosure.

I. INTRODUCTION

One of the first studies about natural convection in rectangular enclosures was a solely experimental study made by Flack et al. [1] in 1979. After this, in 1982 Akinsete and Coleman [2] analysed natural convection of air in a two dimensional laminar right triangular enclosure using numerical methods. Steady state solutions are made for the conditions in which the aspect ratio (A.R.) is between 0.0625 and 1, and Grashof number varies in a range of 800 to 64000. Poulikakos ve Bejan [3] analysed right triangular enclosures in which the upper wall is cold and the lower wall is hot. The conditions that the aspect ratio is closing up to zero are analysed with Rayleigh number varying from $10^3$ to $10^5$.

Lam et al. [4] analysed the natural convection in right triangular, trapezoidal and rectangular enclosures by experimental and numerical methods. In all the cases, bottom wall is hot and side walls are adiabatic. Aspect ratio is kept constant at 4 and the horizontal angle is changed between $0^\circ$ and $25^\circ$.

Tabbarrok and Lin [5] analyzed natural convection in various geometries by finite element method. Square and quarter circle are among the examined geometries. The results that have been found with different Rayleigh numbers are similar with the previous researches.

Karyakin et al. [6] studied laminar natural convection inside isosceles triangular enclosures. Salmun [7,8] used air and water in right triangular geometries. The calculations are made for different Rayleigh number values between $10^2$ and $10^3$ and aspect ratios between 0.1 and 1.

Asan and Namli [9] studied the natural convection during the winter time heating of an attic space. They used finite volume method and analysed cases where Rayleigh numbers vary between 0.25 and 1. Multi-cellular structure is obtained in every enclosure when Rayleigh number equals to $10^5$. As aspect ratio decreases multi-cellular streamlines are observed at lower Rayleigh numbers.


II. MATHEMATICAL MODEL

For a steady state heat transfer with constant thermal and physical properties, laminar and steady incompressible flow with no viscous dissipation, the partial differential equations take the following vectorial forms.

Continuity,

$$\nabla \cdot V = 0$$  \hspace{1cm} (1)

Momentum,

$$\rho (\nabla \cdot V) V = \eta \nabla^2 V - \nabla p - \rho g$$  \hspace{1cm} (2)

Energy,

$$\nabla \cdot (\rho c_p V T) = k (\nabla V) T$$  \hspace{1cm} (3)

Two-dimensional form of these partial different equations in Cartesian coordinates can be written in primitive variable formulation as follows.

Continuity,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$  \hspace{1cm} (4)

x-momentum,

$$\frac{\partial (\rho u u)}{\partial x} + \frac{\partial (\rho v u)}{\partial y} = \eta \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) - \frac{\partial p}{\partial x}$$  \hspace{1cm} (5)

y-momentum, with the Boussinesq approximation for the buoyancy term,

$$\frac{\partial (\rho v v)}{\partial x} + \frac{\partial (\rho v v)}{\partial y} = \eta \left( \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) - \frac{\partial p}{\partial y} + \rho g \beta (T - T_{\text{ref}})$$  \hspace{1cm} (6)

energy,

$$\frac{\partial (\rho u T)}{\partial x} + \frac{\partial (\rho v T)}{\partial y} = k \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right)$$  \hspace{1cm} (7)

Rayleigh number,
III. PHYSICAL MODEL

The triangular grid structure is given in Fig. 1. In this work, natural convection of air with Prandtl number of 0.72 is analysed. The change of the streamlines and isotherms at different Rayleigh numbers ranging from $10^3$ to $10^5$ are obtained numerically and presented as graphics.

![Triangular grid structure](image)

Fig. 1  Triangular grid structure

The four different cases considered in this study is given in Table I. A.R. is abbreviation of Aspect Ratio.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Hypotenuse</th>
<th>Horizontal</th>
<th>Vertical</th>
<th>A.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case I</td>
<td>Cold</td>
<td>Adiabatic</td>
<td>Hot</td>
<td>1</td>
</tr>
<tr>
<td>Case II</td>
<td>Adiabatic</td>
<td>Hot</td>
<td>Cold</td>
<td>1</td>
</tr>
<tr>
<td>Case III</td>
<td>Cold</td>
<td>Hot</td>
<td>Adiabatic</td>
<td>1, 0.5</td>
</tr>
<tr>
<td>Case IV</td>
<td>Cold</td>
<td>Adiabatic</td>
<td>Hot</td>
<td>1</td>
</tr>
</tbody>
</table>

IV. NUMERICAL MODEL

Navier Stokes governing equations which are discretized with finite volume method are solved by Fluent 6.0.12 commercial software [12] by using SIMPLE and Upwind Difference methods. Iterations are continued until the convergence is obtained in a 60x60 grid structure.

Before starting to solve the problem, trial calculations are made in 30x30, 45x45 and 60x60 grid structures in order to prove that the problem is grid independent. Solution method is applied to these grid structures and then the calculated Nusselt numbers, maximum values of stream functions and the coordinates of these stream function values in the enclosure are compared. All the comparisons have shown that the change of these values are under 1% between 45x45 and 60x60 grid structures. So the problem is accepted to be grid independent and calculations are made by using 60x60 grid structure in order to get more precise results.

In Case-I, hypotenuse is cold, vertical wall is hot and horizontal wall is adiabatic. Streamlines and isotherms of this case are shown in Fig. 2. As the Rayleigh number is raised, isotherms start to get non-uniform shapes.

![Streamlines and isotherms inside the right triangular enclosure with the Case I boundary conditions for Rayleigh numbers 10^3,10^4 and 10^5, respectively](image)

Fig. 2  Streamlines and isotherms inside the right triangular enclosure with the Case I boundary conditions for Rayleigh numbers 10^3,10^4 and 10^5, respectively.

For Case II, when Rayleigh number is $10^3$, there is a conductive heat transfer inside the triangle and isotherms have an absolute symmetry. But when Rayleigh number is raised to $10^5$, heat transfer turns out to be convective as isotherms get non-uniform shapes. The results are given in Fig. 3.

For Case III, streamlines and isotherms for the case with A.R.=1 is shown in Fig. 4. Stream function values increase from the side to the inner part of the triangle and gets its maximum value in the central cell. If we compare this case with Case II, we can see that the triangle that we analyzed in Case III has lower stream function values when Rayleigh number is equal to $10^3$ and $10^4$. But when Rayleigh number is raised to $10^5$, maximum stream function value in Case III becomes higher than Case II. This shows that convection effect on the heat transfer in Case III is more than Case II.

For A.R.=0.5, streamlines and isotherms are shown in Fig. 5. Multicellular streamlines are also obtained in the present study when Rayleigh number is raised to $10^3$ and aspect ratio is below 1. While Rayleigh number is $10^5$, streamlines are very similar to those in the right triangular enclosure with A.R.=1. But, when Rayleigh number is raised to $10^3$, streamlines transform into a three cells structure.

$$Ra_c = \frac{g \beta \Delta T h^3 \rho^2 c_p}{k \eta}$$ (8)
For Case IV, streamlines and isotherms are shown in Fig. 6. While Rayleigh number is $10^3$, isotherms seem to be symmetrical and uniform. But, with the increase of Rayleigh number, isotherms get a non-uniform structure.

**IV. CONCLUSIONS**

In this study, steady state laminar natural convection in right triangular enclosures is analyzed. Finite volume method is used to discretize the Navier Stokes equations. SIMPLE
algorithm and upwind difference methods are applied to the governing equations. In order to investigate the effects of aspect ratio on the streamline patterns and isotherms, calculations are made on two different triangular enclosures.

REFERENCES


Design and Thermal Analysis of Free Piston Linear Generator Using In Range Extended Electric Vehicles

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Abstract—Today, battery electric vehicles (BEV) have zero emission (tank to wheel) and very high efficiency. However, the most important obstacle of BEV is insufficient range. This disadvantage can be eliminated in term of range extender systems. Range extender system like generator can charge battery when required. Free Piston Linear Generator (FPLG), Wankel engine, Piston Internal Combustion Engine, Gas Turbine Engine and Fuel Cell Engine can be used as range extender unit.

In this study, opposed-piston free-piston linear generator which can be used in low weight electric vehicles, which has spark ignition, 153 cm3 volume, and gasoline direct fuel injection was designed via SOLIDWORKS® software. Thermal analysis of the engine were performed by means of ANSYS® software using temperature in the literature.

Finally, the engine design is determined to suit thermal operating conditions. It is find out that this system can be used as a range extender unit.

Keywords—Finite Element Method, Thermal Analysis, Free Piston Linear Generator, Computer Aided Design.

I. INTRODUCTION

Energy sources of conventional Internal Combustion Engines (ICE), oil reserves, are gradually in decreasing. Also, adverse effects of conventional ICE on the environment have led to many car manufacturers to product electric car. The inefficiency in ICE’s with low speed and, despite inefficient work with the reason of stop-start urban traffic, energy with regenerative braking, the electric car back in the storage and low speed is an advantage with less energy consumption. While the conventional ICE cars have low efficiency in both too low and too high engine speed and in start-stop city traffic, the electric cars have regenerative braking and consume less energy in low speed.

ICEs have different efficiencies a torques with different speeds, so it cannot operate with maximum efficiency, continuously. Unlike ICE, electric motors can give maximum torque in a wide speed ranges and can work with maximum efficiency in a wide torque ranges.

The forthcoming of electric vehicles are promising, because electric vehicles have no emission during operation. However, current battery technology is not at the desired level owing to short range and long charging times, which is the biggest obstacle in the development of battery electric vehicles. Although Electric cars for daily use are sufficient, they are still not suitable for long-distance travel. For this reason, to solve this problem, in the place of adding some battery unit to electrical car, which causes both an extra weight to car and extra costs, it can be added a range extender unit. Range extender unit has fuel station in anywhere and it can be charge to car’s battery while driving. In this way, car which is both can charge from mains and, if needed, FPLG can charge the batteries using gasoline, diesel or LPG. Vehicle will be made suitable for long trips [1, 3]. Furthermore, range extender can be made portable.

Many engines can be used as range extender unit such as internal combustion engines, gas turbine engines, wankel engines, and fuelcell engines etc. However, free piston linear engine may be smaller volume, lighter, and also high efficiency. Because these engines do not have the crank-rod mechanism although it works like a conventional internal combustion engines. Linear motion of pistons directly converted to electrical energy by means of the linear alternator instead of converting circular motion. Hence efficiency does not loss and weight and volume do not increase due to auxiliary units (Fig.1).

Free piston linear engine and generator have been designed and produced as prototype since the mid-twentieth century. Especially, companies such as Pempek Systems (Australia), Volvo, DLR (Germany), Micron AG (Switzerland) and Toyota have made free-piston linear generator design [4]. Table 1 shows the basic characteristics of the FPLG [2].

![Illustration of the part of the free-piston linear generator](image-url)
The REXEL study estimates the weight of a free piston linear generator with a central combustion unit at 55.9 kg. This weight involves the power electronics needed to run the FPLG. The power density for this prototype is 350 W/kg and the volumetric power density of FPLG is 470 W/l. Former experimental studies showed that the combustion unit could easily achieve an efficiency of 36% and efficiency of engine is about 36% and cost is approximate 2100 € per unit. Yet cost can be reduced to 1500 € per unit using mass production. FPLG with modular size and low weight is a good alternative for range extender units for electric vehicles. Vehicle can extend its range up to a 300 kilometers with adding just about 100 kg (including tank etc.) [1, 2].

II. MODELING OF ENGINE

Computer-aided design (CAD) is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design. CAD is used to increase the productivity of the designer, to improve the quality of design, to improve communications through documentation and to create a database for manufacturing [5].

Free piston linear engine for range extended electric vehicles was designed using CAD software (SOLIDWORKS®) in order to analyze thermal using finite element method. The basic technical characteristics of the engine which was analyzed are given in Table 2.

The literature (Fig. 2) [1, 6].

Table 2

<table>
<thead>
<tr>
<th>Engine type</th>
<th>Free piston engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>diameter of cylinder (mm)</td>
<td>46</td>
</tr>
<tr>
<td>Stroke (mm)</td>
<td>46</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>10:1</td>
</tr>
<tr>
<td>Volume of engine (cm³)</td>
<td>153</td>
</tr>
</tbody>
</table>

Piston, cylinder, wrist pin and rod were redesigned based on the design in the literature (Fig. 2) [1, 6].

Temperature in cylinder change between 100oC and 2500oC and Pressure in cylinder change between 0.8 and 70 bar [18]. So, Cylinder to withstand these conditions are usually made of ductile cast iron grade or steel.

In our design, GGG40 material is selected benefiting from literature, due to damping capacity, good wear and temperature resistance, good machinability, and inexpensive to produce. For cooling, fins were added to cylinder.

By reason of moving at different speed and direction in cylinder, piston should be made of the lightweight material in order to decrease inertia force. Piston of gasoline engines are usually made of AISi including 12% silicon. As ratio of silicon in AISi go up, thermal expansion, wear rate and machinability go down [18]. In our design, AISi12CuNi is selected. Piston are designed as D-cup.

By virtue of free-piston linear engine, only axial forces come to rod. Thus, it is exposed to less load than conventional engines. AISI 4140 is selected for rod material. Rod has unusual shape, because engine designed has not crankshaft.

As FPLG has not crankshaft, rod does not angular movements. So rod pin fix rod and piston. Moreover rod pin, rod and piston can be monolithic. However, it is designed conventionally.

Piston, rod, rod pin and cylinder are designed according to the desired properties benefiting from the literature. Alternator is drawn as represent. Then, parts designed are assembled (Fig. 3 and 4).
III. THERMAL ANALYSIS OF ENGINE PARTS

A. Mathematical Formulation

The temperature $T(x, y, z, t)$ as a function of coordinate parameters and time satisfies a parabolic differential equations. It can be expressed as follows called heat equation,

$$\frac{k_x}{x^2} \frac{\partial^2 T}{\partial x^2} + \frac{k_y}{y^2} \frac{\partial^2 T}{\partial y^2} + \frac{k_z}{z^2} \frac{\partial^2 T}{\partial z^2} + Q = \rho c_p \frac{\partial T}{\partial t}$$

where $Q(x, y, z, t)$ is the source or sink rate of heat in a domain (W/m²), $c_p$ is the specific heat at constant pressure (kJ/kg°C) and $k$ is the thermal conductivity (W/m°C). The essential boundary condition on the boundary and the natural boundary condition can be defined, respectively, as

$$T(x, y, z, t) = T_i(x, y, z, t)$$

$$k_n \frac{\partial T}{\partial n} + q_p + h(T - T_o) + \sigma \epsilon (T^4 - T_o^4) = 0$$

where $k_n$ is the thermal conductivity normal to the surface, $q_p (x, y, z, t)$ is a prescribed flux (W/m²), $h$ is the heat transfer coefficient for convection (W/m²C), $\sigma$ is Stefan–Boltzmann constant (W/m²C⁴), $\epsilon$ is the emissivity and $T^{\infty}$ is the ambient temperature for convection and/or radiation. Boundary condition becomes nonlinear when radiation is included or the convective heat transfer coefficient is temperature dependent. Besides the boundary conditions, the initial condition must be specified for a heat transfer analysis:

$$T(x, y, z, 0) = T_{in}(x, y, z)$$

B. Finite Element Formulation

The domain is broken into a set of discrete volumes or finite elements that are generally unstructured; in 2D, they are usually triangles or quadrilaterals, while in 3D tetrahedral or hexahedra are most often used. The distinguishing feature of finite element method (FEM) is that the equations are multiplied by a weight function before they are integrated over the entire domain [7, 19].

This approximation is then substituted into the weighted integral of the conservation law and the equations to be solved are derived by requiring the derivative of the integral with respect to each nodal value to be zero; this corresponds to selecting the best solution within the set of allowed functions. The result is a set of non-linear algebraic equations [7].

The basis of the finite element method is a piecewise polynomial approximation for the temperature field within each element:

$$T = \sum_{i=1}^{n} N_i T_i$$

where $N_i$ are basis functions dependent only on the type of the element and its size and shape, and “$n$” represents the node number that each element has. Physically, $T_i(t)$ are nodal values of the temperature at time $t$, and mathematically, they are undetermined coefficients. Basically, by using different techniques, Eq. (1) can be reduced to

$$CT + KT = F$$

in which ($K$) is an effective conductivity (stiffness matrix) and ($F$) is an effective load (residual vector). For steady-state analysis, effective load becomes zero. By solving the system, the temperature distribution on the domain is determined [8, 9].

C. Thermal Analysis using Finite Element Method

Numerical analysis was performed to evaluate the temperature gradients in FPLG. The finite element mesh of the FPLG model using ANSYS® is shown in Fig. 5. In the thermal analysis, 209,721 elements are used. 378,597 nodes are also used in thermal analysis.

In this research, thermal boundary conditions were determined by examining the similar works in literature. The temperature values in the cylinder were taken to be average of ICE [9-14].

![Figure 5. Finite element mesh of FPLG designed](image)

Properties of FPLG materials used in thermal analysis are shown in Table 4 [15-17].
TABLE IV
PROPERTIES OF MATERIALS OF FPLG

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal cond. (W/m°C)</th>
<th>Thermal expans. (10^-6°C)</th>
<th>Den. (kg/m³)</th>
<th>Spec. heat (J/Kg °C)</th>
<th>Poiss. ratio</th>
<th>Young’s mod. (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GGG40</td>
<td>42</td>
<td>11</td>
<td>7200</td>
<td>447</td>
<td>0.28</td>
<td>168.5</td>
</tr>
<tr>
<td>AlSi</td>
<td>155</td>
<td>21</td>
<td>2700</td>
<td>960</td>
<td>0.28</td>
<td>80</td>
</tr>
<tr>
<td>AISI 4140</td>
<td>43</td>
<td>11.8</td>
<td>7380</td>
<td>450</td>
<td>0.29</td>
<td>205</td>
</tr>
</tbody>
</table>

Thermal boundary conditions are shown in Fig. 6 and Table 5. Piston thermal boundary conditions consist of the combustion side thermal boundary condition (A), upper ring land (B), lower ring land (C), skirt surface thermal boundary condition (D), outside of cylinder thermal boundary condition (E), surface of rod and rod pin thermal boundary condition (F), inside of cylinder thermal boundary condition (G) and surface of combustion chamber thermal boundary condition (H) [9-14].

The resulting temperature distributions given in Fig. 7 and the resulting heat flux distribution are illustrated in Fig. 8. Temperature distribution in the top and side surface of piston is demonstrated Fig. 9 and Fig. 10, respectively.

Fig. 14 was shown that the surface temperature of the piston decreases from the center to the edge of the piston. The temperature at the center was found as 223°C, it decreased by ~10% and reached to 207°C at the edge of the piston. It indicates that the temperature distribution of the piston surface tends to decrease from the center to the edge of the piston. This situation is valid for the spark ignition engines at real working condition.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Convection coefficient (W/m²K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>650</td>
</tr>
<tr>
<td>B</td>
<td>300</td>
</tr>
<tr>
<td>C</td>
<td>110</td>
</tr>
<tr>
<td>D</td>
<td>85</td>
</tr>
<tr>
<td>E</td>
<td>50</td>
</tr>
<tr>
<td>F</td>
<td>85</td>
</tr>
<tr>
<td>G</td>
<td>85</td>
</tr>
<tr>
<td>H</td>
<td>650</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSION

In order to evaluate the temperature gradients of the FPLG parts, numerical analyses were carried out. Minimum-maximum temperatures and heat fluxes values of piston and cylinder that is found in thermal analyses are shown in Table 6. Maximum temperature of combustion chamber is 231.56°C in the top surface of piston. Maximum heat flux of combustion chamber is 1.09*10⁶ W/m² and minimum heat flux of combustion chamber is 4.76*10⁴ W/m².

<table>
<thead>
<tr>
<th>Minimum-maximum temperatures and heat fluxes in piston and cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum temperature (°C)</td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Top surface of piston</td>
</tr>
<tr>
<td>Inside surface of cylinder</td>
</tr>
<tr>
<td>Bottom surface of piston</td>
</tr>
</tbody>
</table>
V. CONCLUSIONS

Although electric vehicle has advantages such as high efficiency, no emission and much quieter; it is limited by range and take about 4-6 hours to get fully charged. Range extender can eliminate these obstacles. Free piston linear generator in range extender units attract the attention with compact size, relatively simplicity and efficiency.

In this study, cylinder, piston, rod and rod pin of FPLG using in electric vehicles were designed. After defining all boundary and initials conditions in a finite element environment a thermal solution of the FPLG is achieved. According to findings of the analysis, the temperature occurred in engine is acceptable. Hence, it is clearly seen for results of analysis that, if manufactured, engine parts designed can work properly.

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The Effect of Adding EN (2 Ethylhexyl Nitrate) to Diesel-Ethanol Blends on Performance and Exhaust Emissions

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Abstract—In this study, effect of diesel, ethanol and EN blends as fuel in a diesel engine were examined with regard to performance parameters such as brake power, fuel consumption, specific fuel consumption and exhaust emissions such as NOx, CO, CO2. The blends prepared by mixing 10% of ethanol, diesel and EN in different proportions as volume were symbolized as E10 (%10 ethanol and % 90 diesel), E10E2 (%10 ethanol, %2 EN and % 88 diesel), E10E4 (%10 ethanol, %2 EN and % 84 diesel), E10E6 (%10 ethanol, %6 EN and % 84 diesel). The results obtained for these blends were compared with the results for diesel.

Keywords—Alternative fuel, diesel, ethanol, engine performance, exhaust emissions

I. INTRODUCTION

Diesel engines are internal combustion engines in which fuel is injected on pressurized hot air within the cylinder by compression in order to obtain the heat required for ignition. In these engines, combustion occurs, where the ignition conditions is optimum, with self-ignition of fuel-air mixture at the end of a certain ignition delay period following the injection of fuel. The longer ignition delay period leads to uncontrolled combustion of the fuel-air mixture causing an increased amount of fuel air mixture taken into the cylinder. This phenomenon which occurs with the sudden pressure increase causing the engine to work harder and noisy is known as diesel knock. There are many parameters that affect the ignition delay period and diesel knock. These are ambient temperature, ambient pressure, which are two main factors, operational factors such as engine speed, intake air temperature and pressure, engine load, oxygen concentration, and structural factors such as compression ratio, engine cooling conditions, injection quality and fuel factors [1]. When evaluated in terms of fuel, the most important parameter is the cetane number which is a measure of fuel ability to self-ignition. When it is desired to increase the fuel's ignition ability, cetane improver additives are needed to prevent diesel knock and shorten the ignition delay period. These additives shorten the ignition delay period between injection fuel and combustion where the various physical and chemical reactions occur such as atomization, evaporation, mixing with air [2].

The most commonly used cetane improver additive is 2-ethylhexyl nitrate (commonly used as abbreviations of EHN, 2EHN or EN), which improve combustion characteristics and lower burning point by shortening ignition delay [3]. Some researches related with most commonly used cetane improver EN (2 ethylhexyl nitrate) are summarized below. Zhang, et al. have been used a single-cylinder heavy-duty diesel engine fueled with D40 (40% DMF (2,5-dimethylfuran) by volume) with 2% 2-ethylhexyl nitrate addition. Results have showed that ignition delay has been shortened with EHN addition and maximum pressure increase rate has been decreased linearly with the proportion EHN. With high EGR rate, while EHN addition increases NOx emissions, it greatly decreases THC emissions. Based on their results, it has also been stated that EHN addition to D40 has solve trade-off problem between combustion noise and soot emissions for low cetane number oxygenated fuels [3]. Ickes, et al. have investigated the effect of a direct injection, diesel engine LTC operating mode fueled with diesel fuel doped with 2-EHN. It has been detected that adding 2-EHN to the fuel increase NOx emissions for premixed LTC [4]. İleri and Koçar examined the effect of adding antioxidants, butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tert-butylhydroquinone (TBHQ) and 2-ethylhexyl nitrate to B20 biodiesel/diesel blend. It has been observed in their study that addition antioxidants decrease brake specific fuel consumption. EHN is the best in reducing the NOx emissions (4.63%) but each antioxidant led to an increase in CO emission [5]. Li, et al. has examined the effect of three different cetane improvers (2-ethylhexyl nitrate, cyclohexyl nitrate and 2-methoxyethyl ether) with the ratio of 0.3% each one added to the B90M10 methanol/biodiesel blend. It has been confirmed that each cetane improver increase HC and CO concentrations while it reduce NOx concentration and...
smoke. Furthermore no matter they have added to blend, it has not observed any effect on brake thermal efficiency and exhaust temperature [6]. Atmanli has examined the effect of EHN addition at 500, 1000 and 2000 ppm concentration to (70% diesel, 20% hazelnut oil, 10% n-butanol or 10% 1-pentanol by vol.) DnBH and DPnH micro emulsions on fuel properties and engine characteristics. Tests have been carried out for 5 different engine loads (0%, 30%, 60%, 90% and 100%) at 2200 rpm constant engine speed. It has been obtained that EHN addition has no significant effect on density, kinematic viscosity, cloud point, cold filter plugging point (CFPP) or flash point but it has increased cetane numbers approximately 13.12%, 12.26%. It has also confirmed that EHN addition has cause significant reductions in brake specific fuel consumption and (NOx) emissions while it has cause to increase in (CO) emissions [7]. Ileri investigated the effect of 2-ethylhexyl nitrate on engine performance and exhaust emissions of a diesel engine fueled with diesel/sunflower oil/n-butanol (D70S20P10) or 1-pentanol blends (D70S20B10). Results of this study are as follows: Adding EHN to micro emulsion blends has little effect on brake power and brake mean effective pressure while it produce lower NOx, higher CO emission. As EHN concentration increase, brake specific fuel consumption reduces [8]. Relekar et al. have conducted an experimental study to determine the best percentage of additives which ensure maximum efficiency and minimum emissions. For this purpose, experiments have been performed with five samples obtained by blending three different additives. As a result, it has been expressed that best percentages are 70%, 15%, 15% for Dimethyl Carbonate, Ethyl Acetate, and 2Ethylhexyl Nitrate as fuel additive [9].

As mentioned above, there are many studies related to EN in the literature. These are focused on reducing NOx emissions and increasing the cetane number. In this study, the effects of EN (2 ethylhexyl nitrate) addition to ethanol and diesel blends in different ratios (2%, 4%, 6% by vol.) on diesel engine performance and exhaust emissions has been investigated. Performance parameters investigated in this study are brake power, fuel consumption and specific fuel consumption, exhaust emissions are CO, CO₂ and NOx emissions. The results were compared with E10 and the reference diesel fuel.

II. MATERIAL AND METHODS

The experiments were performed on a four-cylinder, water-cooled diesel engine. Other specifications of the engine are given in Table 1.

Diesel procured from gas station and ethanol procured from Konya Sugar Refinery were used for tests and they were performed at five different engine speeds (800, 1100, 1400, 1700, 2000 rpm) using diesel fuel, E10 (%10 ethanol and %90 diesel), E10EN2 (%10 ethanol, %2 EN and %88 diesel), E10EN4 (%10 ethanol, %4 EN and %86 diesel) and E10EN6 (%10 bioethanol, %6 EN and %84 diesel). Fuel properties used during the tests are given in Table 2.

### Table I

<table>
<thead>
<tr>
<th>Engine name</th>
<th>Başak engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number and type of cylinders</td>
<td>4 cylinder – inline</td>
</tr>
<tr>
<td>Cylinder volume, l</td>
<td>2.8</td>
</tr>
<tr>
<td>The engine speed range (rpm)</td>
<td>750 – 2100</td>
</tr>
<tr>
<td>Max. Torque, Nm @ engine speed</td>
<td>225 @ 1100</td>
</tr>
<tr>
<td>Max. Power, Nm @ engine speed</td>
<td>45 @ 1700</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Water-cooled</td>
</tr>
</tbody>
</table>

### Table II

<table>
<thead>
<tr>
<th>Prop. Fuel</th>
<th>Density at 20°C (g/cm³)</th>
<th>Kinematic viscosity at 40°C (mm²/s)</th>
<th>Lower heating value (MJ/kg)</th>
<th>Cetane number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>834.5</td>
<td>2.794</td>
<td>43.14</td>
<td>55.2</td>
</tr>
<tr>
<td>Ethanol</td>
<td>816.0</td>
<td>1.370</td>
<td>27.16</td>
<td>-</td>
</tr>
<tr>
<td>E10</td>
<td>832.8</td>
<td>2.656</td>
<td>41.54</td>
<td>51.4</td>
</tr>
<tr>
<td>E10EN2</td>
<td>835.4</td>
<td>2.631</td>
<td>41.34</td>
<td>54.2</td>
</tr>
<tr>
<td>E10EN4</td>
<td>838.1</td>
<td>2.611</td>
<td>41.14</td>
<td>57.0</td>
</tr>
<tr>
<td>E10EN6</td>
<td>840.8</td>
<td>2.591</td>
<td>40.95</td>
<td>59.8</td>
</tr>
</tbody>
</table>

### III. RESULTS AND DISCUSSION

#### A. Engine Performance

The variation of brake power with engine speed for each test fuel is shown in Fig. 1. Maximum torque has been obtained at 1100 rpm while 1700 rpm is maximum power speed for all fuels. Maximum brake power has the output value of 27.7, 26.8, 27.1, 26.0 and 24.6 for diesel, E10, E10EN2, E10EN4 and E10EN6 at 1700 rpm respectively. For all engine speed, higher power values have been obtained for diesel fuel and average decreases in power compared to diesel fuel are approximately 4.88%, 6.24%, 14.34%, 10.52%. The reasons for reducing engine power are lower cetane number and calorific value when ethanol is used. When these results have been evaluated, maximum average brake power value of E10 is higher than E10EN2, E10EN4 and E10EN6. Although EN addition to fuel improves combustion by increasing the cetane number, it also leads to reduction of performance and power along with lower heating value.
Variation of fuel consumption depending on engine speed for each fuel has been depicted in Fig. 2. The brake specific fuel consumption curve with engine speed for each test fuel is given in Fig. 3. For almost all fuel, it could be observed that raise in engine speed leads to increasing fuel consumption. Highest fuel consumption has been obtained in case the test engine operates with E10, except for 2000 rpm. When taken diesel fuel as a reference, increase in average fuel consumption is 2.06%, 1.00%, 1.85%, 2.46% for E10, E10EN2, E10EN4 and E10EN6 respectively. It can be explained by lower calorific value of diesel being higher than ethanol. When examining specific fuel consumption curve, the average specific fuel consumption is more than approximately 6.5% for E10, 19.2% for E10EN2, 63.1% for E10EN4 and 41.2% for E10EN6 compared to diesel. Namely, the amount of fuel required to generate the same work is less than for the engine fueled with diesel. This situation results from combined effect of lower heating value and density.

B. Exhaust Emissions

The variation of CO emissions, obtained by using diesel, E10, E10EN2, E10EN4 and E10EN6 as fuel in the test engine, with respect to engine speed is given in Fig. 4. As seen, CO emission values obtained for diesel fuel are higher for all engine speeds. Because of the high oxygen-content of ethanol, it is an expected result that CO emissions are lower for fuels containing ethanol within itself. CO emissions have shown a downward trend as engine speed generally increases for all fuel. Maximum CO emission at all engine speed is obtained when operating with diesel. Average decrease of CO emission is %7.93, %20.54, %19.34, %9.01 for E10, E10EN2, E10EN4, E10EN6 respectively.

Fig. 5 shows the variation of CO₂ emission depending on engine speed and fuel. Minimum value of CO₂ emission has been obtained at 2000 rpm while CO₂ emission has the maximum value at 1100 rpm, where engine torque has the
respectively. The average NOx concentration has a positive effect on NOx emission in engine speed. When each rpm is evaluated within its own, EN fuel has the maximum value of brake power compared with other fuels.

As it is seen in Fig. 6., NOx emissions reduces while engine speed increases. The maximum values of NOx emission has been obtained at 800 rpm while NOx emission has the lower value at 2000 rpm, maximum engine speed, for all fuels. When considering fuels, it can be seen that fuel which cause maximum NOx emission is diesel fuel for all engine speed. When each rpm is evaluated within its own, EN concentration has a positive effect on NOx emission in association with the increase in rpm. The average NOx emissions are 882 ppm, 742 ppm, 615 ppm, 748 ppm for diesel, E10, E10EN2, E10EN4 and E10EN6 respectively.

As the results are listed below:
- When assessed in terms of performance, diesel fuel has the maximum value of brake power compared with other fuels.
- The highest values of NOx, CO, CO\(_2\) emissions have also been obtained for diesel fuel.
- By the addition of EN, cetane number has increased approximately 5.45%, 5.17%, and 4.91% for E10EN2, E10EN4 and E10EN6 respectively compared to the E10.
- EN addition of 4% is a critical point with respect to brake power. Because brake power have increased with the increasing EN content in fuel from 2% to 4%. After E10EN4, the behavior of brake power with increasing EN content has changed in the opposite direction.
- E10 has the maximum average brake power value than E10EN2, E10EN4 and E10EN6. The reason is that EN addition to fuel improves combustion so this situation leads to reduction of performance and power.

### IV. CONCLUSIONS

In this study, it has been investigated the use of diesel and ethanol blends doped with EN (2 ethylhexyl nitrate), which is the best known cetane improver, in a diesel engine. Test fuels have been shown as E10, E10EN2, E10EN4 and E10EN6. The tests have been conducted at five different engine speed (800, 1100, 1400, 1700, 2000 rpm) for each fuel. The brake power, fuel consumption, specific fuel consumption as performance parameters and CO, CO\(_2\), and NOx as exhaust emissions have been analyzed and all the results have been compared with diesel fuel.

### REFERENCES

Optimal Tilt Angle for Obtaining Maximum Energy in Photovoltaic System for Siirt Province, Turkey

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Abstract— Renewable energy sources such as wind, sunlight, waves, hydroelectricity and thermal heat etc. are considered as alternative energy sources that can be replaced with energy derived from other energy sources. In particular, Photovoltaic(PV) systems has recently attracted more attention for generating electricity or power to supply energy requirement. Turkey, especially south parts of it, has relatively more solar energy capacity than Europe and west countries. It is very critical measurement that tilt angle between incident sunlight and photovoltaic system plays great changes on producing the power. Thus, we here present an experimental study that reports optimal angle for obtaining maximum energy in photovoltaic system for Siirt Province. In addition to the angle, solar irradiance, air moisture level, panel and ambient temperature, current and voltage were also measured. PV performance for a single module was assessed using PV module efficiency, which is defined as ratio of DC energy output from the PV module. Also, other parameters determining power production were studied: solar radiation level for measuring current from PV and temperature of PV for measuring output voltage.

Keywords—PV module, Optimal tilt angle, Solar irradiance, Siirt, Solar power

I. INTRODUCTION

Solar energy recently became a very popular energy source to supply required energy. Thus, interest in using PV systems launched to increase due to its great offers such as environmental benefits, cost effective, and renewable source. Maximum power generation in PV systems depends on atmospheric conditions for example temperature and solar radiation etc. [1]. Thereby, maximum power point tracker (MPPT) technique is needed and then introduced to obtain maximum power from sunlight. Enslin et al [2] introduced a highly efficient maximum power point tracker (MPPT) integrated into PV system and shows that MPPT provides with 25% more energy compared to conventional system. On the other hand, some investigators, in the literature, showed optimal tilt angle for photovoltaic system for maximum power generation in the case of certain cities. Such as, Kacira et al [3] found that optimal angle to place PV system varies through the year and reported the angle as 13° in June while it is 61° in December in the city of Sanliurfa. Hussein et al [4] presented a theoretical study that determines the performance of mono-crystalline silicon type PV modules at different angles and showed that maximum power is obtained while PV system facing south with a tilt angle between 20° and 30°. Also Ibrahim [5] introduced a theoretical approach to calculate optimal angle four times throughout a year, and he stated that according to results, average optimal tilt angle is found to be 14° for summer season while it is 48° for winter in Cyprus. Tang et al [6] investigated optimal angle with using a mathematical model for various months of year in China and their results indicate that in winter seasons, optimum tilt angle is calculated to be (ʎ+18°) in all cities except Chengdu Plain, Chongqing and Guizhou where optimal tilt angle is approximately (ʎ+10°), where ʎ is local latitude. Yakup et al [7] presented an analytical method to determine also optimal tilt angle and to obtain total global solar radiation in Brunei Darussalam and they concluded that annually averaged optimal tilt angle is obtained to be 3.3° for a south facing solar collector.

Theoretical techniques were indicated to obtain optimal tilt angle while collectors are facing through equator based on beam radiation [8,9]. El-Sayed [10] illustrated a mathematical approach to obtain optimal tilt angle taking account of solar reflectivity, latitude effect, number of glass covers and clearing index. Ahmad et al [11] stated a theoretical examination on determining of tilt angle of solar flat-plate collectors at ten different places in the world and they concluded that annually optimal tilt angle is calculated to be nearly equal to latitude of the location. Moreover, Liu et al [12] presented a theory that determines mean daily global radiation which is expressed as following:

\[ H_B = (H - H_d)R_b \]  \hspace{1cm} (1)
Where $H$ and $H_d$ are mean daily global and diffuse radiation for each month and $R_b$ is the ratio of daily averaged beam radiation on tilted surface [11].

$$ R_b = \frac{\cos(\theta - \beta) \cos \alpha \sin w + w_1 (\sin \theta - \beta) \sin \alpha}{\cos \theta \cos \alpha \sin w + w_1 \sin \theta \sin \alpha} \tag{2} $$

Where $\theta$ is latitude, $\alpha$ is the angle of declination, ‘min’ stands for smaller value of two terms in bracket, and $w_1$ is given as [11];

$$ w_1 = \min[\cos^{-1}(-\tan \theta \tan \alpha), \cos^{-1}(-\tan(\theta - \beta) \tan \alpha)] \tag{3} $$

In this paper, we present an experimental technique that identifies optimal tilt angle of PV system facing to south for Siirt Province to obtain maximum energy in summer season. In addition to the angle, solar irradiance, air moisture level, panel and ambient temperature, current and voltage were also measured. PV performance for a single module was assessed using PV module efficiency, which is defined as ratio of DC energy output from the PV module. Also, other parameters determining power production were studied: solar radiation level for measuring current from PV and temperature of PV for measuring output voltage.

II. MATERIAL AND METHODS

**Experimental Setup**

An experimental apparatus, with PV module that allows us to change at the different angles was designed and fabricated in order to determine the change in power of the PV module under the different angles. The pictorial view of the experimental set up is presented in Fig. 1. The set up consist of PV modules (40W and 80 W), multimeter, pyranometer, datalogger and humidity & temperature sensors. The specifications of the pyranometer used in this study are listed in Table 1. The pyranometer is properly suited for the solar irradiative flux in horizontal or tilted configurations.

<table>
<thead>
<tr>
<th>Response time 95% (sec)</th>
<th>Sensitivity (µV/W/m²)</th>
<th>Impedance (Ω)</th>
<th>Operating temperature range (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Approx. 10</td>
<td>Approx. 50</td>
<td>-40 to +80</td>
</tr>
</tbody>
</table>

Fig. 2 shows the schematic picture of a PV module at different angles which was drawn in a CAD program. As it can be seen from the figure, PV system, which exists of 40 W, placed to face south was tilted from $0^\circ$ to $50^\circ$ to observe the obtained solar energy from sunlight in Siirt Province. Siirt is located at $37^\circ$ 56 N and 41 57 E and 895 m above sea level in the Southern East of the Anatolia. The averaged data have taken between 21st May 2016 and 15th June 2016. Measurement time started at 8:00 am and ended at 5:00 pm. While PV system was tilted for each event, current and voltage values were measured. After determining optimal angle, PV system which exists of 80 W, was used and placed at optimal angle to obtain total solar radiation curve throughout a day. In addition to these values, solar irradiance, air irradiance, air moisture level, panel and ambient temperatures were also measured in this study.

A circuit based on the simulation model for a PV cell for assessing the I-V characteristic curves of PV module with respect to changes on environmental parameters (temperature and irradiance). P-V characteristics are presented in Fig. 3 by varying irradiance from 200 W/m² to 1000 W/m² under constant temperature. The operating point of a PV under constant irradiance and temperature is the intersection point of the I-V characteristics and the load characteristics. Also, I-V characteristics are presented in Fig. 4 by varying temperature from 0 °C to 75 °C under constant irradiance. They are implemented under a Matlab/
Simulink environment; the most used software by researchers and engineers.

III. RESULTS AND DISCUSSION

Fig. 5 demonstrates experimental results of different tilt angles for 40 W PV module system and solar radiation. Experiments run for 9 hours starting at 8:00 am and ending at 5:00 pm. Based on the results, maximum power, which is approximately 40 W during noon time, occurs when the PV system is tilted between 10° and 20°. However, as the tilt angle increased from 20° to 50°, the power launches to drop as shown in the figure. Minimum obtained power in noon time is found to be about 33 W. Also, solar radiation is also measured throughout the day and maximum radiation is found to be approximately 930 W/m² in noon time. Fig. 6 shows experimental results of 80 W PV module system at 15° tilt angle that maximum power is obtained. As it can be seen from the figure, solar irradiance, air moisture level, panel surface and ambient temperatures are measured. According to the results, air ambient and panel surface temperatures are calculated to be approximately 35 °C and 57 °C relatively.

Moreover, measured maximum current and voltage values for 80 W PV module are found to be about 20 V and 5 A relatively. On the other hand, moisture ratio decreases starting from 50 % down to about 15 % during the day.

IV. CONCLUSION

It is very critical to identify optimal tilt angle for PV system to capture maximum power. Thus, we here present an experimental study that reports optimal angle for obtaining maximum energy in photovoltaic system for Siirt Province. Our experimental results show that optimal tilt angle for Siirt Province is 15 ° that maximum power occurs. In addition to the angle, solar irradiance, air moisture level, panel and ambient temperature, current and voltage were also measured and reported in this study. PV performance for a single module was assessed using PV module efficiency, which is defined as ratio of DC energy output from the PV module. Also, other parameters determining...
power production were studied: solar radiation level for measuring current from PV and temperature of PV for measuring output voltage.

References
Computational Investigation of Turbulent Flow in Pipes

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tkarasu@ogu.edu.tr

Abstract — This original research work presents the results of an extensive study of computational solution of steady, incompressible and axisymmetric developing turbulent flow in circular-sectioned pipes at three different Reynolds numbers. Employing the finite-volume method, a computer program based on the SIMPLE (Semi-Implicit Method for Pressure Linked Equations) algorithm has been developed. Computer solution of the conservation equations of mass and momentum, together with the standard k-ε turbulence model, are obtained using an iterative numerical solution technique. Near the solid boundary, wall-functions are employed. Computational predictions for radial profiles of axial velocity, turbulence kinetic energy, turbulence kinetic energy dissipation rate, effective viscosity, centre-line velocity variation, wall-shear stress and friction coefficient distributions along axisymmetric pipe flow geometry are presented and compared with experimental data. The results of computational investigation are generally in good agreement with experimental measurements.

Keywords — Flow in pipes; k-ε turbulence model; Computations

I. INTRODUCTION

Developing turbulent flow in pipes of circular cross-section is one of the basic flow studies. This flow is basically a transition from a boundary layer-type flow at the entrance to a fully developed flow downstream. The free stream in the inlet region is completely surrounded by the boundary layer, which by diffusion of momentum through laminar and turbulent mechanisms grows in thickness as the distance from the pipe inlet increases. The growing boundary layer accelerates the free stream which eventually loses its identity as the boundary layer merges with it. Following the disappearance of the free stream, further changes occur in the velocity distribution and turbulence structure until the flow attains a fully developed state. Turbulent pipe flow has wide application in the field of engineering. The ability to compute the detailed nature of the behaviour of developing turbulent flow in pipes would lead to the improved design of engineering equipment. In practice, turbulent pipe flow is mostly encountered in: transportation of various liquids and gases in long pipes, heat exchangers, coolant passages of electrical generators, combustion chamber systems and air conditioning and heating systems. Considerable experimental and theoretical works on turbulent flow in pipes have been reported in the literature. Among the most interesting ones are the works of [1]-[26]. In the present computational investigation, the experimental measurements of [7], [8], and [25] have been used for comparison with the numerical computations. The main objective of this investigation is to obtain numerical predictions of steady, incompressible, developing turbulent flow in pipes using the standard k-ε turbulence model [27] with a wall-functions boundary condition, and to compare the results of numerical computations with available experimental measurements in the literature for validation.

II. MATHEMATICAL AND PHYSICAL MODEL

A. Governing Equations and Turbulence Model

With reference to Figure 1, the partial differential equations governing steady, incompressible turbulent flow in cylindrical-polar coordinates are written in the following time-averaged, two-dimensional form, with axial and radial coordinates x and r, respectively, as follows:

$$\frac{\partial}{\partial x}(\rho u) + \frac{1}{r} \frac{\partial}{\partial r}(r \rho v) = -\frac{\partial}{\partial x}\left( r \phi \right) - \frac{1}{r} \frac{\partial}{\partial r}\left( r \phi \right) + S_\phi$$  \(1\)

This represents a transport equation for a general variable \(\phi\). The flow is assumed to remain in radial planes. The variables \(u\) and \(v\) are axial and radial velocity components, \(\rho\) is the fluid density and \(\Gamma_\phi\) is the transport coefficient. The final term, \(S_\phi\), is the source term. The variables, \(\phi\), necessary in this computational investigation are \(u, v, k\) and \(\varepsilon\). Here, \(k\) and \(\varepsilon\) stand for the kinetic energy of turbulence and its dissipation rate, respectively. The turbulence model employed in the present study is the k-ε model of [27]. If \(\phi\) is set equal to unity and \(\Gamma_\phi\) and \(S_\phi\) to zero, \(1\) also represents the equation of continuity. Pressure is derived from the pressure correction equation [28]. The transport equations, coefficients and the source terms are summarised in Table I.

![Fig. 1 Coordinate system and geometry of the pipe flow](image-url)
The finite volume forms of the partial differential equations coupled with the boundary conditions are solved iteratively using a line-by-line solution procedure in conjunction with a tridiagonal matrix form.

D. Computational Details

The numerical computations were performed on an Intel(R) Core(TM) i5-2400 CPU @ 3.10GHz 3.40GHz personal computer. The computational grid distributions for all of the pipe-flow cases studied are depicted in Figures 2, 13 and 23. All the computational grids employed were non-uniformly distributed with finer spacings in the regions of large spatial gradients, i.e., the near-wall region and inlet region of the pipe. Staggered control volumes were used for axial and radial velocity components. All other quantities of interest were calculated at the grid points. The line-by-line method was employed to obtain converged solutions iteratively. Under-relaxation factors were used to promote numerical stability with values of 0.6,0.6,0.8,0.8,0.5 and 0.5 for \( u, v, k, \varepsilon, P \) and \( \mu_e \), respectively. The convergence criterion adopted in the present computations was that the summation of the absolute values of the mass residual in the entire computational domain be less than a prescribed value of \( 10^{-8} \). Grid tests were performed with different grid sizes to obtain an optimum grid-independent solution for each flow case studied. All the computations presented in this study are grid-independent. Table II summarises details of the computational requirements for the flow cases investigated. In this table, \( Re \) is the Reynolds number and \( N \) is the number of iterations performed to obtain a converged solution.

### Table I

<table>
<thead>
<tr>
<th>( \phi )</th>
<th>( \Gamma_0 )</th>
<th>( S_0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>( u )</td>
<td>( \mu_e = \mu + \mu_t )</td>
<td>( \frac{\partial P}{\partial x} + \frac{\partial}{\partial x} (\mu_e \frac{\partial u}{\partial x}) + \frac{1}{r} \frac{\partial}{\partial r} (f \mu_e \frac{\partial v}{\partial r}) )</td>
</tr>
<tr>
<td>( v )</td>
<td>( \mu_e = \frac{\partial P}{\partial x} + \frac{\partial}{\partial x} (\mu_e \frac{\partial u}{\partial x}) + \frac{1}{r} \frac{\partial}{\partial r} (f \mu_e \frac{\partial v}{\partial r}) - 2 \mu_e \frac{v}{r} )</td>
<td></td>
</tr>
<tr>
<td>( k )</td>
<td>( \frac{\mu_e}{\sigma_k} )</td>
<td>( G - \rho \varepsilon )</td>
</tr>
<tr>
<td>( \varepsilon )</td>
<td>( \frac{\mu_e}{\sigma_{\varepsilon}} )</td>
<td>( \frac{\varepsilon}{k} (C_1 G - C_2 \mu \varepsilon) )</td>
</tr>
</tbody>
</table>

**Note:** 1. \( \mu_t = C_\mu \rho k^2/\varepsilon \).

2. Turbulence model constants are assigned the following values [27]:
   \( C_\mu = 0.09, C_1 = 1.44, C_2 = 1.92, \sigma_k = 1.0, \sigma_\varepsilon = 1.3 \)

3. \( G = \mu \left\{ 2 \left[ \left( \frac{\partial u}{\partial x} \right)^2 + \left( \frac{\partial v}{\partial x} \right)^2 + \left( \frac{v}{r} \right)^2 \right] + \left( \frac{\partial u}{\partial r} + \frac{\partial v}{\partial x} \right) \right\} \)

### B. Boundary Conditions

With reference to Figure 1, the boundary conditions for turbulent flow in the pipes studied are given below. At the inlet to the pipe, a uniform axial velocity corresponding to the experimental condition is specified, while the radial velocity is assumed zero. Empirical relationships are employed to assign uniform entrance values to turbulence quantities \( k \) and \( \varepsilon \); that is, \( k=(0.001-0.002) u_b^2 \) and \( \varepsilon=(C_\mu k^{1/2} / 0.02R) \), where \( u_b \) is the bulk velocity and \( R \) is the radius of the pipe.

The pipe section was chosen to be sufficiently long so that fully developed conditions could be assumed to prevail at the outlet; that is, all axial derivatives were assumed to vanish and the radial velocity was assumed zero. At the pipe axis, symmetry is assumed: \( \frac{\partial \phi}{\partial r} = v = 0 \), where \( \phi \) can be any of \( u, k \) or \( \varepsilon \). At the pipe wall, velocity components \( u, v \) and turbulence quantities \( k \) and \( \varepsilon \) are set to zero. The values of \( k \) and \( \varepsilon \) at the near-wall grid points are calculated using the wall-functions of [27]. Initial field values throughout the computational domain were specified properly so as not to cause numerical divergence.

### C. Numerical Solution Procedure

In this computational investigation, employing the conventional finite-volume approach, a computer program based on the SIMPLE algorithm of [28] has been developed. The partial differential equations (1) are discretised by a control-volume-based finite-difference method with a hybrid scheme. The finite-volume forms of the partial differential equations coupled with the boundary conditions are solved iteratively using a line-by-line solution procedure in conjunction with a tridiagonal matrix form.

### Table II

<table>
<thead>
<tr>
<th>Flow Case of</th>
<th>Re</th>
<th>Grid Size ((x)\times(r))</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference [8]</td>
<td>178 000</td>
<td>40 \times 30</td>
<td>270</td>
</tr>
<tr>
<td>Reference [25]</td>
<td>130 000</td>
<td>40 \times 30</td>
<td>279</td>
</tr>
<tr>
<td>Reference [7]</td>
<td>100 000</td>
<td>40 \times 30</td>
<td>627</td>
</tr>
</tbody>
</table>

### III. PRESENTATION AND DISCUSSION OF RESULTS

Computations were carried out for developing turbulent flow in circular-sectioned pipes at three different Reynolds numbers, and the results of computations were compared with the experimental data of [7], [8], and [25]. With air used as the working fluid in the pipe, the experimental measurements of [8] are first selected as the comparison basis for this computational study. The Reynolds number based on the pipe diameter and bulk velocity is \( Re=1.78 \times 10^5 \) (\( Re= \frac{u_b d}{\nu} \), where \( u_b \) is the bulk velocity). For this flow situation, the calculation domain is extended to an axial distance of 128.57 diameters downstream of the inlet section of the pipe. The
computational grid distribution for the axisymmetric pipe flow of [8] is depicted in Figure 2. Figures 3 and 4 show the computational radial profiles of axial velocity in dimensionless form $u/u_c$, and radial distance $r/R$, at axial stations ranging from $x/d=1$ to 128.57, together with experimental measurements of [8]. From these figures, it is seen that the computational axial velocity profile develops along the pipe and shows excellent agreement with experimental measurements at the last cross-section $x/d=128.57$. In Figure 5, the predicted axial variation of centre-line velocity is presented in terms of $u_c/u_b$ and axial distance $x/d$. Here, the centre-line velocity ($u_c$) is normalised with the bulk velocity ($u_b$), and the axial distance is normalised with respect to pipe diameter ($d$). As can be seen from the figure, the predicted axial variation of centre-line velocity increases first until it attains its maximum value and then decreases slightly to its fully-developed value downstream after which it remains constant. In Figure 6, the predicted axial distribution of dimensionless turbulence kinetic energy $k^{0.5}/u_b$ along the symmetry axis of the pipe is shown. As seen from the figure, the turbulence kinetic energy decreases until it attains its minimum value at about $x/d=19$, and thereafter increases sharply along the pipe axis until it reaches its maximum value at about $x/d=48$, and then after showing a little bit decrease it attains its fully-developed value, after which it remains constant along the pipe axis. In Figure 7, the predicted radial profiles of turbulence kinetic energy are plotted in dimensionless form of $k/u_b^2$ and radial distance $r/R$ at the same downstream locations as in Figure 3.

As can be seen from the figure, the predicted radial distribution of turbulence kinetic energy increases over the cross-section as the flow develops along the pipe. Figure 8, on the other hand, shows the predicted radial distribution of turbulence kinetic energy for pipe flow of [8] at $x/d=128.57$. Here, the turbulence kinetic energy is made dimensionless with respect to friction velocity $u^2_\tau$.

Figures 9 and 10 reveal the computational radial profiles of turbulence kinetic energy dissipation rate and effective viscosity, respectively, across the pipe at the same downstream positions as in Figures 3 and 7. Here, the predicted profiles are normalised with respect to maximum values of turbulence kinetic energy dissipation rate $\epsilon_{\text{max}}$ and effective viscosity $\mu_{\text{emax}}$ in the flow field, respectively. These figures show how the calculated turbulence kinetic energy dissipation rate and effective viscosity profiles develop along the pipe.

Fig. 2 Computational grid distribution for pipe flow of [8]

Fig. 3 Comparison of predicted radial profiles of axial velocity along the pipe with experimental data of [8]
Fig. 4 Comparison of predicted radial profile of axial velocity with experimental data of [8] at x/d=128.57

Fig. 5 Predicted axial variation of dimensionless centre-line velocity along the pipe axis of [8]

Fig. 6 Predicted axial distribution of dimensionless turbulence kinetic energy along the pipe axis of [8]

Figure 11 displays the computed variation of the wall-shear stress along the pipe wall, in terms of the ratio $\tau_w / \tau_{wd}$, plotted against nondimensional distance $x/d$ from the inlet of the pipe. The wall-shear stress has been made dimensionless with respect to its fully-developed value, $\tau_{wd}$. For this flow situation, as can be seen from the figure, the fully-developed value of the wall-shear stress is reached at about $x/d=85$. Beyond this location, it remains practically constant. Finally, the computed distribution of the friction coefficient ($C_f = 2 \tau_w / \rho U_b^2$) along the pipe wall, as a function of downstream distance $x/d$, is plotted in Figure 12. As seen from the figure, the friction coefficient exhibits the same trend as the wall-shear stress shown in Figure 11.

Fig. 7 Predicted radial profiles of dimensionless turbulence kinetic energy for pipe flow of [8]
Fig. 8 Predicted radial distribution of turbulence kinetic energy for pipe flow of [8] at x/d = 128.57

Fig. 9 Predicted radial profiles of normalised turbulence kinetic energy dissipation rate for pipe flow of [8]

Fig. 10 Predicted radial profiles of normalised effective viscosity for pipe flow of [8]
The predicted radial profiles of axial velocity along the pipe in dimensionless form \( u/u_c \), and radial distance \( r/R \), at axial locations ranging from \( x/d = 0.6 \) to 96.15 are plotted in Figures 14 and 15, and compared with the experimental data of [25]. As seen from the figures, the predicted axial velocity profile develops along the pipe, and at cross-section \( x/d = 87 \) the agreement obtained between the predictions and experimental data is very good. Figure 16, on the other hand, displays the predicted axial variation of dimensionless centre-line velocity \( (u_c) \) along the pipe axis, normalised to bulk velocity \( (u_b) \) and plotted as a function of downstream distance normalised to pipe diameter \( (d) \). As can be seen from the figure, the predicted axial variation of centre-line velocity increases until it reaches its maximum value and then decreases slightly to its fully-developed value after which it remains constant. In Figure 17, the predicted axial distribution of dimensionless turbulence kinetic energy \( k^{0.5}/u_b \) along the symmetry axis of the pipe is revealed. As seen from the figure, the turbulence kinetic energy decreases until it attains its minimum value at about \( x/d = 20 \), and thereafter increases sharply along the pipe axis until it reaches its maximum value at about \( x/d = 45 \), and then after showing a little bit decrease it attains its fully-developed value, after which it remains constant along the pipe axis. In Figure 18, the predicted radial profiles of turbulence kinetic energy are displayed in normalised form of \( k/u_b^{2} \) and radial distance \( r/R \) at the same downstream stations as in Figure 14. As can be seen from the figure, the computed radial distribution of turbulence kinetic energy increases over the cross-section as the flow develops along the pipe, except near the wall region at which it decreases slightly with increasing axial distance. Figures 19 and 20 give the predicted radial profiles of turbulence kinetic energy dissipation rate and effective viscosity, respectively, across the pipe at the same downstream locations as in Figures 14 and 18. These figures indicate how the predicted turbulence kinetic energy dissipation rate and effective viscosity profiles develop along the pipe flow configuration of [25]. In Figure 21, the predicted variation of the wall-shear stress in nondimensional form of \( \tau_w/\tau_{wd} \) along the pipe wall is given as a function of downstream distance normalised to pipe diameter. For this flow case, as can be seen from the figure, the fully-developed value of the wall-shear stress \( \tau_{wd} \) is attained at about \( x/d = 73 \). Beyond this location, it remains practically constant. Finally, the computed distribution of the friction coefficient \( (C_f = 2 \tau_w/\rho U_b^2) \) along the pipe wall, as a function of downstream distance \( x/d \), is plotted in Figure 22. As seen from the figure, the friction coefficient exhibits the same trend as the wall-shear stress shown in Figure 21.
Fig. 14 Comparison of predicted radial profiles of axial velocity along the pipe with experimental data of [25]

Fig. 15 Comparison of predicted radial profile of axial velocity with experimental data of [25] at x/d=87

Fig. 16 Predicted axial variation of dimensionless centre-line velocity along the pipe axis of [25]

Fig. 17 Predicted axial distribution of dimensionless turbulence kinetic energy along the pipe axis of [25]
Fig. 18 Predicted radial profiles of normalised turbulence kinetic energy for pipe flow of [25]

Fig. 19 Predicted radial profiles of normalised turbulence kinetic energy dissipation rate for pipe flow of [25]

Fig. 20 Predicted radial profiles of normalised effective viscosity for pipe flow of [25]
The third flow configuration is for the pipe flow experiment of [7] with air used as the working fluid. The Reynolds number of the pipe flow is $Re=1\times10^5$ ($Re=\frac{u_b d}{\nu}$, where $u_b$ is the bulk velocity). For this flow situation, the computational domain is extended to an axial distance of 240.7 diameters downstream from the inlet plane of the pipe. The computational grid distribution for the pipe flow of [7] is indicated in Figure 23. The computed radial profiles of axial velocity along the pipe in dimensionless form $u/u_c$, and radial distance $r/R$, at axial positions ranging from $x/d=3$ to 240.7 are depicted in Figures 24 and 25, and compared with the experimental measurements of [7]. As seen from the figures, the computed axial velocity profile develops along the pipe, and at cross-section $x/d=240.7$ the agreement obtained between the predictions and experimental data is excellent.

Fig. 21 Predicted variation of dimensionless wall-shear stress along the pipe wall of [25]

Fig. 22 Computed distribution of friction coefficient along the pipe wall of [25]

Fig. 23 Computational grid distribution for pipe flow of [7]

Fig. 24 Comparison of computed radial profiles of axial velocity along the pipe with experimental data of [7]
IV. CONCLUDING REMARKS

The main concluding remarks from the computational study of the present investigation can be summarised as follows. Developing turbulent flow in pipes of circular cross-section at three different Reynolds numbers has been computed numerically employing the standard k-ε turbulence model. Using the finite-volume method, a computer program based on the SIMPLE algorithm of [28] has been developed. The performance of the standard k-ε turbulence model has been investigated for developing turbulent pipe flow. The computed radial profiles of axial velocity, turbulence kinetic energy, turbulence kinetic energy dissipation rate, effective viscosity, axial variation of centre-line velocity, wall-shear stress and friction coefficient distributions along the pipe are presented and, wherever available, compared with experimental measurements reported in the literature. The results of computational investigation are generally in good accord with the experimental measurements.

REFERENCES

Experimental Determination of Drag Coefficients for Torpedo-Like Geometries in an Open Wind Tunnel

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Abstract— Autonomous underwater vehicles (AUVs) or unmanned air vehicles (UAVs) as a part of defence systems are evaluated for underwater or atmospheric conditions, respectively. In these operation conditions, these vehicles are expected to have some critical properties such as energetic performance, longer range, less deflection from the target. These expectations are generally related with less resistance or drag. Due to these aforementioned issues, drag coefficient carries importance in the design of a defence vehicle. In the application, drag coefficient for a model can be measured with force measurement systems in water or wind tunnels. With this approach, drag coefficients of torpedo-like geometries have been obtained by force measurement system integrated to an open wind tunnel in Fluid Mechanics Laboratory of Aksaray University. Different models have been investigated for Reynolds numbers range of Re = 6.6 x 10^4 and Re = 33.1 x 10^4. The elliptical cross-sectional one has only been investigated at several attack angles varying from α = 0˚ to α = 30˚. The effects of torpedoes having various leading edge types with changing length/diameter (L/D) ratios and trailing edges of the elliptical cross-sectional one with different numbers of appendages on drag coefficients have been considered. When the wind speeds increase, drag coefficients decrease owing to shrinking wake region size. In addition, while attack angles rise, drag coefficients also increase because of flow separation around leading edge. Various leading edge types just like elliptical cross-sectional one, circular cross-sectional one and swaged headed one have been examined; the lowest drag coefficient has been found to be an elliptical cross-sectional one whereas the highest one was yielded for the swaged headed one. Furthermore, the more appendages added to trailing sections of torpedo-like geometries, the higher drag coefficients have been obtained. Moreover, inverse relationship between L/D ratios and drag coefficients has been observed.

Keywords— Defence vehicles, drag coefficient, Reynolds number, torpedo, wind tunnel

I. INTRODUCTION

Examination the deeps of seas and abyssal ocean zones for the development of defence systems, improves the motivation of scientists and engineers to keep on their researches and studies. It is known that oceans and seas cover the two thirds of our world, but oceans and seas have not drawn enough interest when analogized with land and atmosphere. Another point to be emphasized is that underwater research vehicles or underwater defence vehicles are exposed to huge forces than land and air vehicles. When their manoeuvre capabilities are considered, investigation of the hydrodynamic characteristics for these aforementioned vehicles is very crucial for engineering community. In this content, torpedo and torpedo-like geometries are described in the classification of unmanned (autonomous) underwater vehicles. In this study, drag coefficients of torpedo-like geometries have been determined with respect to the experimental results obtained from the force measurement system in an open wind tunnel. In this perspective, many studies related with the hydrodynamic characteristics of these underwater vehicles were presented before. Feldkamp (1987) has examined the drag, energetic cost and efficiency associated with the locomotion of a sea lion. In the experiments, four sea lions have been investigated in terms of drag coefficient. They have obtained the results for frontal areas as follow C_D = 0.07 at Re = 2.03 x 10^4; C_D = 0.069 at Re = 2.13 x 10^4 and C_D = 0.046 at Re = 2.87 x 10^4 [1]. Beheshi et al. (2009) have studied on the flow physics around an airship in a water tunnel and have carried out experiments to determine the aerodynamic characteristics of these aircrafts in the range of Re = 1.09 x 10^4 and Re = 7.05 x 10^4. They have measured the drag on a small scaled model of the airship to identify a laminar-to-turbulent boundary layer transition. It has been observed that the body with appendages resulted in 30% higher drag compared to the bare hull [2]. Husaini et al. (2009) have simulated the cooperative AUV motion by using CFD to study on drag variation in terms of distance between two AUVs and position arrangement. They have stated that the drag of the follower AUV in position arrangement is always lower than leading drag [3]. Abrebeekooh and Rad (2011) have obtained the drag force acting on a tubular frustum designed eligible for underwater conditions. All experiments have been completed in the range of Reynolds numbers between 10^7 and 7 x 10^7. These experimental results have been confronted with numerical results of k-ε turbulence model. The geometry has been reversed to obtain results for different L/D ratios. In other words both at upstream and downstream, the tubular frustum has been placed with respect to its small diameter. By this way, different flow directions have been attained. In case of the small diameter of the tubular
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frustum at upstream, less drag force has been observed owing to low pressure [4]. Mirzaei et al. (2012) have investigated the drag of different aircraft aft bodies both experimentally and numerically. Experiments have been carried out in a wind tunnel and numerical analyses have been done by using CFD code. They have found that changing the passenger aircraft aft body to the basic cargo aft body led to a 28% increase in the drag coefficient [5]. Pan et al. (2012) have utilized the numerical simulations to determine the hydrodynamic coefficients of a SUBOFF submarine model. Steady and unsteady Reynolds Averaged Navier-Stokes (RANS) simulations have been carried out for the flow analyses. Dynamic mesh method has been adopted to examine the manoeuvre capabilities. The computational results have been verified by comparison with experimental data and therefore this method has been recommended by authors [6]. Okawa et al. (2013) have measured the drag exerted on different archery arrows in a wind tunnel for various attack angles. In the experimental study, Reynolds numbers range from 9 × 10^5 and 2.4 × 10^6. They have stated that drag coefficient decreased due to increase in Reynolds number. On the other hand, when the angle attack increases drag coefficient also rises [7]. Saeidinezhad et al. (2015) have presented a study on experimental investigation of hydrodynamic characteristics of a submersible vehicle model. A wind tunnel with smoke flow visualization technique has been used to test the submarine model with all its appendages at length based Re = 6.6 × 10^6 for different pitch angles between α = -10° and α = 27°. Drag coefficients have been examined with respect to Reynolds numbers of Re = 4.7 × 10^6 and Re = 8 × 10^6. A perpetual increment in both drag and lift coefficients has been observed due to raise in pitch angles. Flow separation near to nose tip has been monitored as non-axisymmetric nose shape existed [8]. Fureby et al. (2016) have studied a generic conventional submarine at yaw angle of 10°. Wind tunnel with PIV has been utilized as an experimental setup and LES turbulence model has been used for the numerical study [9]. Skarolek and Karabelas (2016) have investigated the flow over an aircraft wing by LES turbulence model at Re = 2.5 × 10^6 while the angles of attack varying from 4° to 12°. The results indicated that maximum drag decreased by approximately 40 at low attack angles [10]. The aim of this study is to determine the drag coefficients of different torpedo-like geometries positioned in an open wind tunnel for several cases at various Reynolds numbers, experimentally.

II. MATERIAL AND METHOD

In this study, drag coefficients of different torpedo-like geometries having various length/diameter (L/D) ratios have been determined experimentally. Here, the diameter of the torpedo-like geometry is D = 40 mm for the elliptical cross-sectional and circular cross-sectional ones while the diameter of the swage headed one is D = 45 mm. While the diameter of the geometry is constant, the length/diameter ratios are L/D = 5 to L/D = 8.125. Only several angles of attack changing from α = 0° to α = 30° have been considered for the elliptical cross-sectional one. Furthermore, the elliptical cross-sectional one has been examined by adding appendages to its trailing edge. All torpedo-like geometries used in the experiments have been shown in Fig. 1. However, these geometries have been indicated with the length/diameter ratio of L/D = 5. Other L/D ratios (such as L/D = 6.125, 6.875 and 8.125) have been attained by adding attachment part into the middle of the torpedo-like geometries.

![Elliptical cross-sectional torpedo-like geometry](image1)

![Cylindrical cross-sectional torpedo-like geometry](image2)

![Swaged headed torpedo-like geometry](image3)

![Elliptical cross-sectional torpedo-like geometry with four appendages](image4)

Fig. 1 Torpedo-like geometries used for the experiments performed in the open wind tunnel

The experimental results have been obtained from the force measurement system in an open wind tunnel in Fluid Mechanics Laboratory of Aksaray University for Reynolds numbers ranging from Re = 6.6 × 10^4 to Re = 33.1 × 10^4.

A. Experimental Setup

An open wind tunnel with a force measurement system has been used in the facilities of Fluid Mechanics Laboratory at Aksaray University in Aksaray/Turkey as indicated in Fig. 2. The wind tunnel is the classic experiment system for aerodynamic flow experiments. The open wind tunnel has been manufactured by German brand called as G.U.N.T. Hamburg Gerätebau GmbH. Technical drawing of the system has been shown in Fig. 3.
The dimensions of the open wind tunnel which is G.U.N.T. Hamburg HM 170 are 2860 mm x 860 mm x 1700 mm and these are length, width and height of the wind tunnel, respectively. Fan motor power is 2.25 kW and the wind tunnel is able to reach up to 2800 rpm with variable frequency control. With respect to catalogue data, fan head is given as 500 Pa and 2.5 m/s of maximum air flow is provided. A body is positioned in a measurement section having cross-sectional area of 292 x 292 mm² through the approximate length of 420 mm. In the force measurement part of the wind tunnel, the diameter of the model holder is 4 mm and its length to centre of the model is defined as 225 mm. The measurement range of the system is up to 10 N with the resolution of 0.1 N in terms of both forces of drag and lift [11].

The wind tunnel consists of (1) inlet contour, (2) flow straightener, (3) nozzle, (4) measurement section, (5) model, (6) force sensor, (7) display and control unit, (8) diffuser, (9) switch cabinet, (10) inclined tube manometer and (11) axial fan as seen in Fig. 4 [11].

The model being studied remains at rest while the flow medium is set in motion, and thus the desired flow around the model is generated. It is an "Eiffel" type open wind tunnel used to demonstrate and measure the aerodynamic properties of various models. For this purpose, air is drawn from the environment and accelerated.

The air flows around a model, in a measurement section. The air is then decelerated in a diffuser and pumped back by a fan. The carefully designed nozzle contour and a flow straightener ensure a uniform velocity distribution with little turbulence in the closed measurement section. The flow cross-section of the measurement section is square. The built-in axial fan with outlet guide vane system and a variable-speed drive is characterised by an energy-efficient operation at high efficiency. Air velocities up to 28 m/s can be reached in this open wind tunnel. This type of wind tunnel is only suitable for relatively low air velocities in the range of 0 < Mach number of Ma < 0.2. Turbulence intensity of the wind tunnel is estimated as 3%. The system is equipped with an electronic two-component force sensor. Lift and drag forces are detected and displayed digitally. The air velocity in the measurement section is displayed on the inclined tube manometer. The tube manometers are utilized for measurement of the pressure in drag bodies [11].

All experiments have been carried out in this wind tunnel for different free-stream air speeds which are $U_\infty = 5$ m/s, 7.5 m/s, 10 m/s, 12.5 m/s, 15 m/s, 17.5 m/s, 20 m/s, 22.5 m/s and 25 m/s corresponding Reynolds numbers of $Re = 6.6 \times 10^4$, 9.9 $\times 10^4$, 13.2 $\times 10^4$, 16.6 $\times 10^4$, 19.9 $\times 10^4$, 23.2 $\times 10^4$, 26.5 $\times 10^4$, 29.8 $\times 10^4$ and 33.1 $\times 10^4$, respectively. Attack angles are $\alpha = 0^\circ$, 4°, 8°, 12°, 15° and 30° and these values have only been considered for the elliptical cross-sectional torpedo-like geometry. The effects of torpedo-like geometries having various leading edge types with changing length/diameter (L/D) ratios on drag coefficients have been examined while different leading edge types are elliptical cross-sectional one, circular cross-sectional one and swaged headed one. The length/diameter ratios (L/D) have been given as L/D = 5, 6.125, 6.875 and 8.125, respectively. Moreover, the elliptical cross-sectional one has been investigated by adding three and four appendages to its trailing edge.

The force measurement system of the wind tunnel presents the drag force acting on the model. For this reason, drag coefficients ($C_D$) of different torpedo-like geometries in this study have been calculated by using Eq. (1):
\[ C_D = \frac{2F_D}{\rho AV_{\infty}^2} \] (1)

Here, \( F_D \) stands for the drag force acting on the model. As the model holder has been used in the experiments for the stability of the model, drag force has taken place on the model holder. Drag force value \( (F_{DH}) \) of the model holder has been subtracted from the total measured value of the drag force \( (F_D) \) to calculate the actual drag force value \( (F_D) \) acting on the torpedo-like geometry as seen in Fig. 5 [11].

![Fig. 5 Error caused by model holder [11]](image)

In Eq. (1), \( \rho \) is the density of air and it has been taken as \( \rho = 1.205 \text{ kg/m}^3 \) at 20 \( ^\circ \text{C} \) temperature and 1 atm pressure. By the way, \( A \) is the frontal reference area of the torpedo-like geometry. In the experiments, it alters with respect to the diameter of the torpedo-like model used and also appendages added. The areas of the torpedo-like geometries have been given in Table I.

<table>
<thead>
<tr>
<th>Models</th>
<th>( A ) (m(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elliptical cross-sectional one with no appendages</td>
<td>0.001256</td>
</tr>
<tr>
<td>Elliptical cross-sectional one with three appendages</td>
<td>0.001280</td>
</tr>
<tr>
<td>Elliptical cross-sectional one with four appendages</td>
<td>0.001288</td>
</tr>
<tr>
<td>Swaged cross-sectional one</td>
<td>0.001256</td>
</tr>
</tbody>
</table>

In Eq. (1), \( V_{\infty} \) symbolizes the free-stream velocity which is called as \( U_v = 5 \text{ m/s}, 7.5 \text{ m/s}, 10 \text{ m/s}, 12.5 \text{ m/s}, 15 \text{ m/s}, 17.5 \text{ m/s}, 20 \text{ m/s}, 22.5 \text{ m/s} \) and \( 25 \text{ m/s} \). Drag coefficient results obtained with respect to the Eq. (1) have been given in the following comparison graphics for different cases considered.

![Fig. 6 Angle of attack effect on drag coefficients of an elliptical cross-sectional torpedo-like geometry for different Reynolds numbers](image)

TABLE I

| REFERENCE FRONTAL AREAS OF THE TORPEDO-LIKE GEOMETRIES |

In Fig. 6, drag coefficients of elliptical cross-sectional torpedo-like geometries with different angles of attack have been presented at various Reynolds numbers. Attack angles of \( \alpha = 0^\circ, 4^\circ, 8^\circ, 12^\circ, 15^\circ \) have been considered for \( Re = 6.6 \times 10^4, 9.9 \times 10^4, 13.2 \times 10^4, 16.6 \times 10^4, 19.9 \times 10^4, 23.2 \times 10^4, 26.5 \times 10^4, 29.8 \times 10^4 \) and \( 33.1 \times 10^4 \). According to the given comparison graphic, maximum drag coefficients at whole cases have been obtained for the free-stream air speed of 5 m/s corresponding \( Re = 6.6 \times 10^4 \). At \( Re = 6.6 \times 10^4 \), \( C_D = 1.0995 \) is at attack angle of \( \alpha = 0^\circ \); \( C_D = 1.1571 \) is at attack angle of \( \alpha = 4^\circ \); \( C_D = 1.4008 \) is at attack angle of \( \alpha = 8^\circ \); \( C_D = 1.4922 \) is at attack angle of \( \alpha = 12^\circ \); \( C_D = 1.7671 \) is at attack angle of \( \alpha = 15^\circ \) and \( C_D = 2.2215 \) is at attack angle of \( \alpha = 30^\circ \). When the free-stream air speeds (also corresponding Reynolds numbers) acting on the torpedo-like geometry increase, less drag coefficient values have been attained. It has been found that \( C_D = 1.0995 \) for \( Re = 6.6 \times 10^4 \); \( C_D = 0.5303 \) for \( Re = 9.9 \times 10^4 \); \( C_D = 0.3903 \) for \( Re = 13.2 \times 10^4 \); \( C_D = 0.2704 \) for \( Re = 16.6 \times 10^4 \); \( C_D = 0.1892 \) for \( Re = 19.9 \times 10^4 \); \( C_D = 0.1640 \) for \( Re = 23.2 \times 10^4 \); \( C_D = 0.1594 \) for \( Re = 26.5 \times 10^4 \); \( C_D = 0.1553 \) for \( Re = 29.8 \times 10^4 \) and \( C_D = 0.1538 \) for \( Re = 33.1 \times 10^4 \) for the attack angle of \( \alpha = 0^\circ \). Another result is that while the attack angles of the torpedo-like geometry rise, there are increment obtained in drag coefficients related with increasing frontal reference areas. At the value of \( Re = 33.1 \times 10^4 \) calculated for \( U_v = 25 \text{ m/s} \), it has been obtained that \( C_D = 0.1538 \) for \( \alpha = 0^\circ \), \( C_D = 0.1574 \) for \( \alpha = 4^\circ \), \( C_D = 0.1881 \) for \( \alpha = 8^\circ \), \( C_D = 0.2280 \) for \( \alpha = 12^\circ \), \( C_D = 0.4873 \) for \( \alpha = 15^\circ \) and \( C_D = 0.7380 \) for \( \alpha = 30^\circ \).
Fig. 7 indicates drag coefficients of various leading edge types with length/diameter (L/D) ratio of L/D = 5. Here, different leading edge types are elliptical cross-sectional one, circular cross-sectional one and swaged headed one. The effects of torpedo-like geometries having various leading edge types have been examined for $Re = 6.6 \times 10^4$, $9.9 \times 10^4$, $13.2 \times 10^4$, $16.6 \times 10^4$, $19.9 \times 10^4$, $23.2 \times 10^4$, $26.5 \times 10^4$, $29.8 \times 10^4$ and $33.1 \times 10^4$. With respect to the given graphic, maximum drag coefficients for all cases have been detected for the free-stream air speed of 5 m/s corresponding $Re = 6.6 \times 10^4$. At $Re = 6.6 \times 10^4$, $C_D = 1.1624$ is for the circular cross-sectional one; $C_D = 1.0995$ is for the elliptical cross-sectional one and $C_D = 1.0262$ is for the swaged headed one. While the free-stream air speeds (also corresponding Reynolds numbers) acting on the torpedo-like geometry rise, drag coefficients decrease. At $Re = 33.1 \times 10^4$, $C_D = 0.1580$ is for the circular cross-sectional one; $C_D = 0.1538$ is for the elliptical cross-sectional one and $C_D = 0.1502$ is for the swaged headed one. It has been found that $C_D = 1.1624$ for $Re = 6.6 \times 10^4$; $C_D = 0.6216$ for $Re = 9.9 \times 10^4$; $C_D = 0.4255$ for $Re = 13.2 \times 10^4$; $C_D = 0.3056$ for $Re = 16.6 \times 10^4$; $C_D = 0.2129$ for $Re = 19.9 \times 10^4$; $C_D = 0.1943$ for $Re = 23.2 \times 10^4$; $C_D = 0.1784$ for $Re = 26.5 \times 10^4$; $C_D = 0.1647$ for $Re = 29.8 \times 10^4$ and $C_D = 0.1580$ for $Re = 33.1 \times 10^4$ for the circular cross-sectional one. Furthermore, it has been obtained that $C_D = 1.0995$ for $Re = 6.6 \times 10^4$; $C_D = 0.5303$ for $Re = 9.9 \times 10^4$; $C_D = 0.3903$ for $Re = 13.2 \times 10^4$; $C_D = 0.2704$ for $Re = 16.6 \times 10^4$; $C_D = 0.1892$ for $Re = 19.9 \times 10^4$; $C_D = 0.1640$ for $Re = 23.2 \times 10^4$; $C_D = 0.1594$ for $Re = 26.5 \times 10^4$; $C_D = 0.1553$ for $Re = 29.8 \times 10^4$ and $C_D = 0.1538$ for $Re = 33.1 \times 10^4$ for the elliptical cross-sectional one. Moreover, it has been observed that $C_D = 1.0262$ for $Re = 6.6 \times 10^4$; $C_D = 0.4495$ for $Re = 9.9 \times 10^4$; $C_D = 0.3295$ for $Re = 13.2 \times 10^4$; $C_D = 0.2585$ for $Re = 16.6 \times 10^4$; $C_D = 0.1779$ for $Re = 19.9 \times 10^4$; $C_D = 0.1629$ for $Re = 23.2 \times 10^4$; $C_D = 0.1562$ for $Re = 26.5 \times 10^4$; $C_D = 0.1522$ for $Re = 29.8 \times 10^4$ and $C_D = 0.1502$ for $Re = 33.1 \times 10^4$ for the swaged headed one. As a result of passive flow control, the lowest drag coefficient has been found to be the swaged headed one whereas the highest one was yielded for the circular cross-sectional one.

Drag coefficients of the elliptical cross-sectional ones with different numbers of appendages on trailing edges have been shown in Fig. 8 for the length/diameter (L/D) ratio of L/D = 5. Here, it has been considered with or without appendages. In the presence of appendages, three or four appendages have been added to the trailing edges of the geometry. These aforementioned cases have been examined for $Re = 6.6 \times 10^4$, $9.9 \times 10^4$, $13.2 \times 10^4$, $16.6 \times 10^4$, $19.9 \times 10^4$, $23.2 \times 10^4$, $26.5 \times 10^4$, $29.8 \times 10^4$ and $33.1 \times 10^4$. In the graphic, maximum drag coefficients have been observed for the free-stream air speed of 5 m/s corresponding $Re = 6.6 \times 10^4$. For $Re = 6.6 \times 10^4$, $C_D = 1.4288$ is for the elliptical cross-sectional one with four appendages; $C_D = 1.3216$ is for the elliptical cross-sectional one with three appendages and $C_D = 1.0995$ is for the elliptical cross-sectional one without any appendages. After the free-stream air speeds (also corresponding Reynolds numbers) acting on the torpedo-like geometry increase, the decrease in drag coefficients has been observed. It has been interpreted that $C_D = 1.4288$ for $Re = 6.6 \times 10^4$; $C_D = 0.8413$ for $Re = 9.9 \times 10^4$; $C_D = 0.5050$ for $Re = 13.2 \times 10^4$; $C_D = 0.3688$ for $Re = 16.6 \times 10^4$; $C_D = 0.2532$ for $Re = 19.9 \times 10^4$; $C_D = 0.2245$ for $Re = 23.2 \times 10^4$; $C_D = 0.2066$ for $Re = 26.5 \times 10^4$; $C_D = 0.1805$ for $Re = 29.8 \times 10^4$ and $C_D = 0.1745$ for $Re = 33.1 \times 10^4$ for the elliptical cross-sectional one with four appendages. In addition, it has been obtained as $C_D = 1.3216$ for $Re = 6.6 \times 10^4$; $C_D = 0.7803$ for $Re = 9.9 \times 10^4$; $C_D = 0.4564$ for $Re = 13.2 \times 10^4$; $C_D = 0.3400$ for $Re = 16.6 \times 10^4$; $C_D = 0.2456$ for $Re = 19.9 \times 10^4$; $C_D = 0.2170$ for $Re = 23.2 \times 10^4$; $C_D = 0.1993$ for $Re = 26.5 \times 10^4$; $C_D = 0.11756$ for $Re = 29.8 \times 10^4$ and $C_D = 0.1701$ for $Re = 33.1 \times 10^4$ for the elliptical cross-sectional one with three appendages. What’s more, it has been found that $C_D = 1.0995$ for $Re = 6.6 \times 10^4$; $C_D = 0.5303$ for $Re = 9.9 \times 10^4$; $C_D = 0.3903$ for $Re = 13.2 \times 10^4$; $C_D = 0.1779$ for $Re = 19.9 \times 10^4$; $C_D = 0.1629$ for $Re = 23.2 \times 10^4$; $C_D = 0.1562$ for $Re = 26.5 \times 10^4$; $C_D = 0.1522$ for $Re = 29.8 \times 10^4$ and $C_D = 0.1502$ for $Re = 33.1 \times 10^4$ for the elliptical cross-sectional one with two appendages. The more appendages added to trailing sections of torpedo-like geometries, the higher drag coefficients have been obtained because of increase in frontal reference areas.
In Fig. 9, drag coefficients of elliptical cross-sectional torpedo-like geometries with the length/diameter (L/D) ratios have been given at various Reynolds numbers. Different elliptical torpedo-like geometries having length/diameter (L/D) ratios of L/D = 5, 6.125, 6.875 and 8.125 have been considered for $Re = 6.6 \times 10^4$, $9.9 \times 10^4$, $13.2 \times 10^4$, $16.6 \times 10^4$, $19.9 \times 10^4$, $23.2 \times 10^4$, $26.5 \times 10^4$, $29.8 \times 10^4$ and $33.1 \times 10^4$. With respect to the given graphic, maximum drag coefficients at all cases have been obtained for the free-stream air speed of 5 m/s corresponding $Re = 6.6 \times 10^4$. At $Re = 6.6 \times 10^4$, $C_D = 0.7083$ is for length/diameter (L/D) ratio of L/D = 5; $C_D = 0.9286$ is for length/diameter (L/D) ratio of L/D = 6.125; $C_D = 0.7976$ is for length/diameter (L/D) ratio of L/D = 6.875 and $C_D = 0.7083$ is for length/diameter (L/D) ratio of L/D = 8.125, respectively. While the free-stream air speeds (also corresponding Reynolds numbers) acting on the torpedo-like geometry rise, decrease in drag coefficient values has been observed. Minimum values of drag coefficients have been seen for the circular cross-sectional torpedo-like geometry with the length/diameter ratio of L/D = 8.125 as $C_D = 0.1552$ for $Re = 8.125 \times 10^4$. In Fig. 10, different circular cross-sectional torpedo-like geometries having length/diameter (L/D) ratios of L/D = 5, 6.125, 6.875 and 8.125 have been considered for $Re = 6.6 \times 10^4$, $9.9 \times 10^4$, $13.2 \times 10^4$, $16.6 \times 10^4$, $19.9 \times 10^4$, $23.2 \times 10^4$, $26.5 \times 10^4$, $29.8 \times 10^4$ and $33.1 \times 10^4$. With respect to Fig. 10, maximum drag coefficients for entire situations have been attained for the free-stream air speed of 5 m/s corresponding $Re = 6.6 \times 10^4$. At $Re = 6.6 \times 10^4$, $C_D = 1.1624$ is for length/diameter (L/D) ratio of L/D = 5; $C_D = 1.0360$ is for length/diameter (L/D) ratio of L/D = 6.125; $C_D = 0.8737$ is for length/diameter (L/D) ratio of L/D = 6.875 and $C_D = 0.8034$ is for length/diameter (L/D) ratio of L/D = 8.125, respectively. While the free-stream air speeds (also corresponding Reynolds numbers) acting on the torpedo-like geometry increase, decrease in drag coefficient values has been obtained. Minimum values of drag coefficients have been seen for the circular cross-sectional torpedo-like geometry with the length/diameter ratio of L/D = 8.125 as $C_D = 0.1527$ for $Re = 33.1 \times 10^4$. Additionally, when the length/diameter ratios increase, drag coefficients decrease for the elliptical cross-sectional ones. At the value of $Re = 33.1 \times 10^4$ calculated for $U_\infty = 25$ m/s, it has been obtained that $C_D = 0.1527$ for length/diameter (L/D) ratio of L/D = 8.125 for the elliptical cross-sectional ones. In addition, when the length/diameter ratios increase, drag coefficients decrease as in the Fig. 8 for the elliptical cross-sectional ones. At the value of $Re = 33.1 \times 10^4$ calculated for $U_\infty = 25$ m/s, it has been obtained that $C_D = 0.1538$ for length/diameter (L/D) ratio of L/D = 5; $C_D = 0.1521$ for length/diameter (L/D) ratio of L/D = 6.125; $C_D = 0.1509$ for length/diameter (L/D) ratio of L/D = 6.875 and $C_D = 0.1501$ for length/diameter (L/D) ratio of L/D = 8.125 for the elliptical cross-sectional ones.
At \( \text{Re} = 6.6 \times 10^4 \) as in Fig. 10, \( C_D = 1.0262 \) is for length/diameter (L/D) ratio of \( L/D = 5 \); \( C_D = 0.9000 \) is for length/diameter (L/D) ratio of \( L/D = 6.125 \); \( C_D = 0.7798 \) is for length/diameter (L/D) ratio of \( L/D = 6.875 \) and \( C_D = 0.6754 \) is for length/diameter (L/D) ratio of \( L/D = 8.125 \), respectively. While the free-stream air speeds (also corresponding Reynolds numbers) acting on the torpedo-like geometry rise, decrease in drag coefficient values has been observed. Minimum values of drag coefficients have been obtained for the swaged headed torpedo-like geometry with the length/diameter ratio of \( L/D = 8.125 \) as \( C_D = 0.6754 \) for \( \text{Re} = 6.6 \times 10^4 \); \( C_D = 0.3689 \) for \( \text{Re} = 9.9 \times 10^4 \); \( C_D = 0.2489 \) for \( \text{Re} = 13.2 \times 10^4 \); \( C_D = 0.2296 \) for \( \text{Re} = 16.6 \times 10^4 \); \( C_D = 0.1710 \) for \( \text{Re} = 19.9 \times 10^4 \); \( C_D = 0.1568 \) for \( \text{Re} = 23.2 \times 10^4 \); \( C_D = 0.1515 \) for \( \text{Re} = 26.5 \times 10^4 \); \( C_D = 0.1491 \) for \( \text{Re} = 29.8 \times 10^4 \) and \( C_D = 0.1461 \) for \( \text{Re} = 33.1 \times 10^4 \). In addition, when the length/diameter ratios increase, drag coefficients decrease as in the Fig. 10 for the swaged headed ones. At the value of \( \text{Re} = 33.1 \times 10^4 \) calculated for \( U_o = 25 \text{ m/s} \), it has been obtained that \( C_D = 0.1502 \) for length/diameter (L/D) ratio of \( L/D = 5 \); \( C_D = 0.1500 \) for length/diameter (L/D) ratio of \( L/D = 6.125 \); \( C_D = 0.1475 \) for length/diameter (L/D) ratio of \( L/D = 6.875 \) and \( C_D = 0.1461 \) for length/diameter (L/D) ratio of \( L/D = 8.125 \) for the swaged headed torpedo-like geometries.

IV. CONCLUSIONS

In this study, drag coefficients of torpedo-like geometries have been obtained by force measurement system integrated to an open wind tunnel. Different torpedo-like models have been investigated in the range of \( \text{Re} = 6.6 \times 10^4 \) and \( \text{Re} = 33.1 \times 10^4 \). The elliptical cross-sectional one has only been examined at various attack angles varying from \( \alpha = 0^\circ \) to \( \alpha = 30^\circ \). The effects of torpedoes having various leading edge types with changing length/diameter (L/D) ratios and trailing edges of the elliptical cross-sectional one with different numbers of appendages on drag coefficients have been considered. For all cases, maximum drag coefficient values have been obtained for the free-stream air speed of 5 m/s corresponding \( \text{Re} = 6.6 \times 10^4 \) and the free-stream air speeds (also corresponding Reynolds numbers) acting on the torpedo-like geometry increase, less drag coefficient values have been attained. Another result is that while the attack angles of the torpedo-like geometry increase, there are increment obtained in drag coefficients related with increasing frontal reference areas. As a result of passive flow control, the lowest drag coefficient has been found to be the swaged headed one whereas the highest one was yielded for the circular cross-sectional one. Another deduction is that, the more appendages added to trailing sections of torpedo-like geometries, the more drag coefficients have been obtained because of increase in frontal reference areas. In addition, when the length/diameter ratios (L/D) increase, decrease in drag coefficients has been observed.

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REFERENCES

CFD-Based Performance Analyses of a Francis Turbine in Several Guide Vane Positions

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Abstract— Hydraulic turbines are turbomachines that transforms the hydraulic energy into mechanical energy. Francis turbines are the most common hydraulic turbine type in use. A francis turbine consists of several components such as spiral case, stay vanes, guide vanes, runner and draft tube. Design and performance analysis of these turbines requires much time. During the recent years, Computational Fluid Dynamics (CFD) has been frequently used to examine turbomachinery performance since CFD is more effective in terms of time and economy. In this study, a francis turbine is designed with respect to head and discharge values which are significant parameters for preliminary design. Performance analyses have been carried out with commercial CFD codes by changing guide vane positions. For each position of guide vanes, turbine efficiency and velocity and pressure distributions are obtained. In conclusion, the optimum guide vane position is determined for the maximum turbine performance.

Keywords—Francis Turbine, Guide Vanes, Performance Analysis, Computational Fluid Dynamics (CFD)

I. INTRODUCTION

In recent years, hydraulic energy becomes one of the significant renewable energy type due to its high potential and efficient transformation into electrical energy. The structures which transforms hydraulic energy into electrical energy are called hydroelectric power plants. The process of transformation is provided by two steps. First, hydraulic energy transforms into mechanical energy by way of a hydraulic turbine. Then a rotating shaft, which rotates simultaneously with turbine runner, drives a generator to transform the mechanical energy into electrical energy. Although there are a lot of turbine types used for transforming energy, Francis turbines are the most common type in use due to their efficient working principle.

Francis turbine is a reaction turbine. That means there should be a pressure drop between inlet and outlet of the turbine because both kinetic and potential energy of water are used. Francis turbines are generally used in mid-range head and discharge values. Head and discharge values are significant because the performance of turbine depends on these values. So the selection of turbine types is carried out via these parameters. The types of turbine depending on head and discharge values are given in Figure 1.

Fig. 1 Variation of turbine types depending on head and discharge values[5]

A francis turbine comprises of several components. These components are named as spiral case, stay vanes, guide vanes, runner and draft tube. These components play important roles while turbine is working. Spiral case is the structure which
surrounds the whole turbine components. This component has several sections which decrease towards its outlet section. Spiral case distributes the inflow that comes from penstock through the stay vanes on equal pressure values in its each section. Stay vanes are the fixed blades which are responsible of regulating the flow towards to guide vanes. Guide vanes are the configurable blades that control the flow rate value which enters the runner. As performance of the turbine depends on flow rate value, it can be said that guide vanes directly effects the performance of a Francis turbine. Turbine runner is the main component where the transformation of hydraulic energy into mechanical energy occurs. Turbine blades rotate with the water motion that moves out of guide vanes. As transformation of energy provided, water which rotates the runner and gives it to the stream. Water gains pressure due to increasing cross sectional area of draft tube but it never has its former pressure in spiral case inlet. In Figure 2, components of a Francis turbines are shown.

There has been a certain number of studies about Francis turbines in literature. Schweiger [1] examined the dimensionless parameters, geometrical quantities and specific speed of a Francis turbine. Siervo and Leva [2] manifested diagrams and equations about the design of the spiral case, runner and draft tube. Nilsson and Davidson [3] studied the relation between velocity and pressure in a Francis turbine runner by changing trailing edge angle of runner blades. Caillot et al. [4] investigated the design of guide vanes in order to send the water in desired angle and flow rate to the runner.

In this study, the effect of guide vanes positions on turbine efficiency is examined by means of commercial CFD codes. Different guide vane angles are used in several performance analyses and the optimum guide vane position is determined according to the best efficiency value.

II. DESIGN METHODOLOGY

Designing a Francis turbine is a complicated process so it should be done step by step. Five stages are specified: inputs, preliminary design, geometry design, CFD analyses and final design. Thus, a design methodology is established. The stages of design methodology are given in Figure 3.

Head and discharge values are the most significant parameters in designing process. All the preliminary design parameters depend on these two values. Therefore, head and discharge values must be determined in first stage. In this study an actual turbine’s values are used as head and discharge.

After specifying head and discharge values, preliminary design stage starts. In this stage, experimental curves and theoretical data in literature are used for determining main dimensions of components. There’s an order to design components’ main dimensions. First of all, dimensions of runner should be determined based upon it is the inner component between others. Another reason is runner has the smallest diameter and other components’ dimensions are specified by runner diameter. Runner diameter and heights are determined from theoretical data. After runner’s dimensions are determined, guide vanes’ dimensions can be specified. Guide vanes surround the runner, so its diameter should be larger than runners. According to the studies in literature, it’s generally taken as 1.16 times larger than runner’s diameter [5].

\[
D_{\text{guide vanes}} = 1.16D_{\text{runner}} \tag{1}
\]

The number of guide vanes and maximum guide vane angle at full load are determined based on a parameter, named velocity coefficient(Ω). The number of guide vanes are determined from an experimental diagram in literature by way of velocity coefficient. Maximum guide vane angle is determined from
equation (2). Calculation of velocity coefficient is shown in equation (3), (4) and (5).

\[
\alpha = 4(-4\Omega^2 + 13\Omega + 1) \\
\Omega = \omega \sqrt{Q} \\
\omega' = \omega / \sqrt{2gH} \\
Q' = Q / \sqrt{2gH}
\]

Stay vane diameter is selected based on guide vane diameter. Leading edge angle of stay vanes is specified as same as guide vane’s due to flow regulation. After selecting stay vanes diameter, spiral case -the outermost component- parameters are determined. Specification of spiral case parameters is done based on technical data and experimental curves as the same in runner. Spiral case sections are designed based on MATLAB codes [6]. Finally, draft tube parameters are designed. The inlet diameter of draft tube is determined based on runner’s outlet diameter. Other parameters of draft tube are designated by theoretical data in literature as runner and spiral case.

As preliminary design finished, geometry of turbine is created computationally in ANSYS Design Modeler and ANSYS BladeGen. First of all, blade profiles of runner, guide vanes and stay vanes are generated in ANSYS BladeGen module. NACA profiles are used in generating these profiles. These blade profiles are turned into solid geometries and then flow domains of runner, guide vanes and stay vanes are generated. Flow domains of spiral case and draft tube are generated in ANSYS Design Modeler. The whole components are unified at last. The computational design of Francis turbine’s flow domain is shown in Figure 4.

After completing the geometry design, computational fluid dynamics (CFD) analyses are carried out. If the efficiency of turbine is low, based on analyses, guide vane angle is changed and carried the analysis out again until the best efficiency point obtained. When the best efficiency point obtained, it is decided that guide vane angle of this point is the optimum guide vane position. More details of CFD analyses will be given in Chapter III.

### III. COMPUTATIONAL FLUID DYNAMICS

Computational Fluid Dynamics (CFD) codes are common tools in use to predict turbomachinery performance in recent years. In this study, a commercial CFD code, ANSYS v.15 is used to examine turbine performance and flow characteristics. There are some dependents that effect the CFD codes such as boundary conditions, discretization schemes, advection schemes, turbulence models. Some different approaches are used based on the dependents used in analyses.

#### A. Mesh Generation

The flow domains of Francis turbine are meshed in ANSYS ICEM CFD. All components are meshed separately. Tetrahedral and hexahedral elements are used while generating grids.

Face and body sizing are used while meshing the components. By applying proximity and curvature size function, an automatic refinement on grids is carried out for more detailed grids. Despite all components are meshed separately, the mesh domains are assembled for solution. In Figure 5, assembled mesh domain of Francis turbine is shown.

![Grids of Francis Turbine](image)

The grid-dependency is controlled in different types of mesh structures and element numbers and it is obtained that the model is independent from grid. Details of grids and element numbers are given in Table 1 for each components grid structure.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Number of Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spiral Case</td>
<td>1883654</td>
</tr>
<tr>
<td>Stay Vanes</td>
<td>2831218</td>
</tr>
<tr>
<td>Guide Vanes</td>
<td>6044748</td>
</tr>
<tr>
<td>Runner</td>
<td>8470873</td>
</tr>
<tr>
<td>Draft Tube</td>
<td>635949</td>
</tr>
</tbody>
</table>

![Fig. 4 Francis Turbine Flow Domain](image)

![Fig. 5 Grids of Francis Turbine](image)

![Table 1. Details of Grids](image)
B. Boundary Conditions

Boundary conditions are specified as mass flow inlet and static pressure outlet for this study. Inlet boundary condition is defined on spiral case inlet as 4160 kg/s and outlet boundary condition is defined on draft tube outlet as 1 atm. Besides, the reference pressure is defined as 0 atm.

C. Schemes, Models and Approaches

In this study, ANSYS CFX 15.0 is used as commercial Reynolds-Averaged Navier-Stokes codes for modelling turbulent flow. These codes use finite volume method as discretization scheme.

While modelling flow, RNG k-ε is used as turbulence model due to its reliability. As an advection scheme, high resolution is used in solution. The convergence criteria is defined as 10^-5 for the momentum and mass residuals.

Despite the components are designed separately, they are assembled for solution in CFX solver. Thus, some interface approaches are needed to be used. Multiple Reference Frame (MRF) is used to unite interface surface grids. Within the scope of MRF, Frozen Rotor approach is used for interfaces between “runner and guide vanes” and “runner and draft tube”. For the interfaces between “spiral case and stay vanes” and “stay vanes and guide vanes”, General Grid Interface (GGI) approach is used.

IV. RESULTS

After completing CFD analyses, pressure and velocity distributions of each component are obtained. Besides, efficiency values are calculated based on torque values which are obtained from analyses.

Analyses carried out in five different angles. As a result, largest efficiency value, %94, is obtained on the guide vane angle 22. Figure 6 shows the efficiency curve on different guide vane angles.

Pressure and velocity distributions for the most efficient point are given in following figures. In Figure 7, pressure distribution on the mid-plane of spiral case is shown.

Vectors show that water flows regularly on each section of spiral case. Pressure is gradually decreasing towards the stay vanes. Therefore, water velocity increases. As can be seen on pressure contours, pressure distribution is uniform for each section.

Pressure and velocity distribution of guide vanes are shown in Figure 8 and Figure 9.

In Figure 8, it is shown that water flows regularly among the guide vanes. Velocity contours indicate that flow velocity is increasing against the runner. Besides, water flows in right direction according to vectors.

It is clearly seen on Figure 9 that the stagnation point is obtained on the symmetry point of guide vane leading edge. That proves the angle of guide vanes are selected correctly and the flow between components are fixed.
Water enters turbine runner with high velocity after leaving guide vanes axis. Since the water particles hit the runner blades with high velocity, runner blades rotate more efficiently. Thus, hydraulic energy turns into mechanical energy by means of the rotation of shaft which is synchronized with runner rotation. After transforming hydraulic energy into mechanical energy, the water which rotates runner should be carried from runner area.

Draft tube steps in there. Tail water flows into draft tube and moves on inside it. Water has a rotational motion early on in draft tube, but as long as the sections enlarge, flow becomes tranquil and regular. The pressure between inlet and outlet of the draft tube are different because of the increasing cross-sectional area. While flow loses its speed, pressure rises. At the outlet section of draft tube, water stands at atmospheric pressure. In Figure 10, pressure distribution of the mid-plane on draft tube is given.

As can be seen on Figure 10, pressure increases gradually towards the outlet of draft tube. Some high pressure contours occur on inclined wall of draft tube but these are considered as elbow.

All in all, obtained pressure and velocity distributions are approved as appropriate. The final design’s efficiency value is %94.

V. CONCLUSION

In this study, a Francis turbine is designed based on the experimental curves and theoretical data on literature. Computational design of this turbine is actualized on ANSYS Design Modeler and ANSYS BladeGen. Computational grid structures of turbine flow domains are created on ANSYS ICEM CFD. Based on this design, the effects of guide vane positions are investigated in different guide vane angles.

Five different CFD analyses in different guide vane angles are carried out. An efficiency curve is composed based on this analyses. 22 guide vane angle is the point which corresponds the best efficiency point on efficiency curve. For each position of guide vanes, turbine efficiency and velocity and pressure distributions are obtained. As it is mentioned in Chapter IV, pressure and velocity contours prove that flow between components are fixed. Contours are examined and decided as appropriate flow characteristic.

In conclusion, the optimum guide vane position is determined for the maximum turbine performance.

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Numerical Analysis of a Sweep-Twist Wind Turbine Blade

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#Mechanical Engineering Department, Selcuk University
Konya, Turkey

Abstract— Wind energy is being used to generate electricity in many countries all over the world and still the contribution of wind energy to electricity supply increases every day. Researchers work on innovative solutions to increase the efficiency and decrease the cost of wind turbine components, especially those of blades. Various blade designs for different operation conditions are presented in the literature and sweep-twist blades are new type of blades introduced recently. This paper focuses on the numerical investigation of a sweep-twist wind turbine blade using ANSYS-Fluent. NREL Phase VI wind turbine blade is used as the baseline blade and the sweep-twist blade is designed by adding 5% sweep-twist to the tip. Power output and thrust forces are calculated using the simulation results for both original and sweep blades. In addition, results are compared to the experimental data of original NREL Phase VI blade.

Keywords— Wind, Blade, Sweep-twist, CFD

I. INTRODUCTION

Each passing day the need for the use of clean energy sources rises since power production from fossil fuels damage our planet continuously. Within this scope, many developed and developing countries have set some goals to generate some part of energy consumption from renewable energy sources. For instance, the ministry of energy of Turkey has decelerated the strategic plan for 2015-2019 an increase in installed renewable energy capacity by nearly twice compared to the value of 2013 [1]. Hence, wind energy – recognized as an efficient renewable energy source – has taken the role of being one of the leading alternative sources. In past few decades, huge improvements have taken place in wind power technology especially on the design of blades which influences the efficiency directly. Within this scope, many experts who are interested in aerodynamics contributed the literature with some studies about various blade designs. Sweep-twist wind turbine blades were firstly introduced by Sandia National Laboratories of U.S. Energy Department. After completing the research, they presented a final report (2010) where they introduced analysis results of Sweep Twist Adaptive Rotor (STAR) blades [2]. In the report, they stated that the STAR technology provided significantly greater energy capture – about 10-12% compared to baseline Z48 turbines - without higher operating loads on the turbine. The results are also presented by Ashwill et al. (2010) in a conference [3]. Sing and Ahmed performed a study about design and performance testing of a small wind turbine rotor for low wind speed applications. A new airfoil was designed and the performance of a 2-bladed rotor for low Re application fitted to an Air-X marine 400 W wind turbine was tested at a wind speed range of 3-6 m/s. Authors stated that the new 2-bladed rotor produced more electrical power at the same freestream velocity in comparison with the baseline 3-bladed rotor [4]. Wang and Zhan (2013) investigated the performance of a micro-wind turbine using CFD and concluded that the performance of the wind rotor with semi-circular blades is comparable to that of the semi-cylindrical wind rotor, and is slightly lower than that of the helically twisted wind rotor [5]. Bai et al. (2013) designed a 10 kW horizontal axis wind turbine blade and performed aerodynamic investigation using numerical simulation of it. It has been reported that CFD is a good method compared to the improved BEM theory method on the aerodynamic investigation of HAWT blades [6]. Koc et al. (2015) studied the hydrodynamic performance of a twin-blade hydrofoil numerically and experimentally in three dimensions for tip speed ratios ranging between 1.5 and 5.5. Authors reported that the optimum tip speed ratio of 3.5 for twin blade turbine is too low comparing the optimum tip speed ratio of 5.0 for the slat hydrofoil or standard hydrofoil turbine applications and added that the wind and hydrokinetic turbines with the twin blade hydrofoil can operate in lower wind and current speeds [7]. A detailed review of aerodynamic developments on small horizontal axis wind turbine blades is presented by Kartikeyan [8]. In the present study, numerical investigation of the aerodynamics around a sweep-twist wind turbine blade using ANSYS-Fluent is performed. NREL Phase VI wind turbine blade is used as a baseline blade and the sweep-twist blade is designed by adding an offset as much as 5% of the blade diameter to the tip of the blade. Results are compared with the original blade.

II. NREL VI AND SWEEP-TWIST BLADES

NREL Phase IV wind turbine blade is selected as a baseline blade. It has S809 airfoil sections from root to tip and a pitch angle of 3 degrees. The description of the NREL Phase VI blade is given in Table 1 and chord and twist variations along the blade are given in Table 2 [9]. In this study, some sections
including the ones which have radial distance between 0.660 and 1.257 and the one with 3.185 radial distance are excluded since the sections are very close to the previous section.

### TABLE I
**Description of NREL Phase VI blade [9]**

<table>
<thead>
<tr>
<th>Number of blades</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotor diameter</td>
<td>10.06 m</td>
</tr>
<tr>
<td>Cone angle</td>
<td>0 degrees</td>
</tr>
<tr>
<td>RPM</td>
<td>71.6</td>
</tr>
<tr>
<td>Blade tip pitch angle</td>
<td>3 degrees (down)</td>
</tr>
<tr>
<td>Blade profile</td>
<td>S809</td>
</tr>
<tr>
<td>Blade chord length</td>
<td>0.358 m – 0.728 m (linearly tapered)</td>
</tr>
<tr>
<td>Twist angle</td>
<td>Non-linear twist along the span</td>
</tr>
</tbody>
</table>

### TABLE II
**Chord and twist variations along the NREL VI rotor blade [9]**

<table>
<thead>
<tr>
<th>Section</th>
<th>Radial Distance r (m)</th>
<th>Span Station r/5.029 m</th>
<th>Chord length (m)</th>
<th>Twist (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Hub</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.508</td>
<td>0.101</td>
<td>0.218</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.660</td>
<td>0.131</td>
<td>0.218</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0.883</td>
<td>0.176</td>
<td>0.183</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>1.008</td>
<td>0.200</td>
<td>0.349</td>
<td>6.7</td>
</tr>
<tr>
<td>6</td>
<td>1.067</td>
<td>0.212</td>
<td>0.441</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>1.133</td>
<td>0.225</td>
<td>0.544</td>
<td>13.4</td>
</tr>
<tr>
<td>8</td>
<td>1.257</td>
<td>0.250</td>
<td>0.737</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>1.343</td>
<td>0.267</td>
<td>0.728</td>
<td>28</td>
</tr>
<tr>
<td>10</td>
<td>1.510</td>
<td>0.300</td>
<td>0.711</td>
<td>30</td>
</tr>
<tr>
<td>11</td>
<td>1.648</td>
<td>0.328</td>
<td>0.697</td>
<td>31</td>
</tr>
<tr>
<td>12</td>
<td>1.952</td>
<td>0.388</td>
<td>0.666</td>
<td>34</td>
</tr>
<tr>
<td>13</td>
<td>2.257</td>
<td>0.449</td>
<td>0.636</td>
<td>39</td>
</tr>
<tr>
<td>14</td>
<td>2.343</td>
<td>0.466</td>
<td>0.627</td>
<td>40</td>
</tr>
<tr>
<td>15</td>
<td>2.562</td>
<td>0.509</td>
<td>0.605</td>
<td>49</td>
</tr>
<tr>
<td>16</td>
<td>2.867</td>
<td>0.570</td>
<td>0.574</td>
<td>56</td>
</tr>
<tr>
<td>17</td>
<td>3.172</td>
<td>0.631</td>
<td>0.543</td>
<td>62</td>
</tr>
<tr>
<td>18</td>
<td>3.185</td>
<td>0.633</td>
<td>0.542</td>
<td>63</td>
</tr>
<tr>
<td>19</td>
<td>3.476</td>
<td>0.691</td>
<td>0.512</td>
<td>68</td>
</tr>
<tr>
<td>20</td>
<td>3.781</td>
<td>0.752</td>
<td>0.482</td>
<td>78</td>
</tr>
<tr>
<td>21</td>
<td>4.023</td>
<td>0.800</td>
<td>0.457</td>
<td>80</td>
</tr>
<tr>
<td>22</td>
<td>4.086</td>
<td>0.812</td>
<td>0.451</td>
<td>81</td>
</tr>
<tr>
<td>23</td>
<td>4.391</td>
<td>0.873</td>
<td>0.420</td>
<td>84</td>
</tr>
<tr>
<td>24</td>
<td>4.696</td>
<td>0.934</td>
<td>0.389</td>
<td>85</td>
</tr>
<tr>
<td>25</td>
<td>4.780</td>
<td>0.950</td>
<td>0.381</td>
<td>86</td>
</tr>
<tr>
<td>26</td>
<td>5.029</td>
<td>1.000</td>
<td>0.358</td>
<td>87</td>
</tr>
</tbody>
</table>

The 3-D drawings of the blades are given in Fig. 1. To draw the sweep-twisted blade, all the same properties as NREL Phase IV blade are used except a tip offset which is 5% of the blade diameter (0.25 m) is given beginning from the middle of the blade. The sections from the beginning of the sweep – located at the 2.562 m radial distance- until the tip of the blade are interpolated. Dimensions of the original and sweep-twisted blades are given in Figure 2.

![Fig. 1 3-D drawings of the NREL PHASE VI (up) and sweep-twisted blade (down)](image_url)

![Fig. 2 Dimensions of the original and sweep-twisted blade](image_url)

### III. NUMERICAL SIMULATION

In this study, 3-D air flow around the wind turbine blade is simulated with ANSYS Fluent 16. The dimensions of the flow field are 12 R in the stream-wise direction extruded from a circle having 3 R dimension where R is the radius of the blade. The domain of flow field including boundary conditions is given in Fig. 3.

![Flow field and boundary conditions](image_url)
Meshing of the fluid domain is performed using ANSYS meshing. The thickness of the first cell to the wall was kept at $2 \times 10^{-5}$ m to obtain proper $y^+$ value for the used turbulence models. In order to increase the mesh quality, sharp trailing edge of the blades is rounded. Mesh construction and a sliced section of the mesh around the blade and rotor hub can be seen in Fig. 4. Mesh independence study is performed for various models containing different number of elements and a model containing 9.8 million elements is used.

**k-\(\varepsilon\) Turbulence Model**

One of the turbulence models used for tests is \(k-\varepsilon\) Realizable turbulence model. The \(k-\varepsilon\) model is a two-equation turbulence model consists of turbulence kinetic energy and turbulence dissipation rate equations given below.

\[
\begin{align*}
\frac{\partial k}{\partial t} + \frac{\partial (\rho u_j k)}{\partial x_j} &= P_k - \rho \varepsilon + L_k \quad \text{(1)} \\
\frac{\partial \varepsilon}{\partial t} + \frac{\partial (\rho u_j \varepsilon)}{\partial x_j} &= \frac{\varepsilon}{k} \left( \frac{\mu_t}{\sigma_\varepsilon} \frac{\partial k}{\partial x_j} + \frac{\varepsilon}{k} \frac{\partial^2 k}{\partial x_j^2} + \frac{1}{3} \frac{\partial u_j}{\partial x_j} \right) + \frac{\varepsilon^2}{k} + C_{1\varepsilon} \frac{k}{
\end{align*}
\]

where $P_k$ is turbulent production and viscosity are defined by the Eq. 3 and Eq. 4, respectively.

\[
P_k = \tau_{ij} \frac{\partial u_i}{\partial x_j}
\]

\[
\mu_t = \rho_f \mu_t \frac{k^2}{\varepsilon} \quad \text{(4)}
\]

**k-\(\omega\) SST turbulence model**

This turbulence model combines both \(k-\varepsilon\) and \(k-\omega\) models. The original \(k-\varepsilon\) turbulence model has the problem of over predicting the shear stress that might delay or prevent the separation where inverse pressure gradients are possessed, and the original \(k-\omega\) model is very sensitive to free stream values that are specified outside the shear layer [11]. The original \(k-\omega\) model is defined by the Equations 5 and 6 [11,12].

\[
\begin{align*}
\frac{\partial (\rho k)}{\partial t} + \frac{\partial (\rho u_j k)}{\partial x_j} &= P - \beta \mu \omega + \frac{\partial}{\partial x_j} \left( \mu + \frac{\rho \mu}{\sigma_\omega} \frac{\partial k}{\partial x_j} \right) \quad \text{(5)} \\
\frac{\partial (\rho \omega)}{\partial t} + \frac{\partial (\rho u_j \omega)}{\partial x_j} &= \frac{\varepsilon}{k} \left( \frac{\mu + \sigma_\omega \rho k}{\omega} \frac{\partial \omega}{\partial x_j} \right) + \frac{C_3 \rho}{\omega} \frac{\partial \omega}{\partial x_j} \frac{\partial \omega}{\partial x_j} \quad \text{(6)}
\end{align*}
\]

**IV. VALIDATION OF THE SOLVER**

The solver is validated against experimental data of NREL Phase VI. The mechanical power of numerical and experimental tests is presented in Fig. 5. The mechanical power is simply calculated by multiplying rotation speed, $\Omega$ (rad/s) by torque, $T$ (Nm) obtained from FLUENT as given in Eq. 7. As seen from the Fig. 5, experimental and numerical power outputs are in general agreement. However, after 10 m/s CFD predictions cannot predict the stall very accurately. Thrust force measurements and CFD predictions are in very good agreement as it can be seen from the Fig. 6. Also, pressure distributions for 5 m/s case at 47% and 80% span are in agreement with experimental data as shown in Fig. 7.
This study compared the original NREL Phase VI blade with a sweep-twisted model of it. Power results are compared in Fig. 8 for the sweep-twist and original blade. It is observed that wind turbine blades sweep-twisted to the leading edge side of the blade generate lower power than the original blade. In addition, it is obtained that the $k - \omega$ SST turbulence model predicts lower power output than the $k - \varepsilon$ Realizable. In Fig. 9, the thrust force for sweep-twist and original blade are compared and results show that the sweep-twisted blade has lower thrust force (more than 10%) at each wind speed except 20 and 25 m/s. The pressure distributions for 5 m/s case at 47% and 80% span are compared in Fig. 10. It is clear that the pressure distribution on the original blade is able to generate more power than the sweep-twist blade.
V. CONCLUSIONS

In this paper, mechanical power outputs and thrust forces of original NREL VI and a sweep-twist wind turbine blade are compared. Both k - ω SST and k - ε Realizable turbulence models predicted the thrust force very close to experimental measurements. In addition, CFD predictions of mechanical power output are found to be overall in agreement with experimental data, however, after the wind speed of 10 m/s when the stall occurs, CFD predictions were not very successful. Generally, the k - ω SST turbulence model predicted lower power output than k - ε Realizable for both original NREL Phase VI and sweep-twisted blade. Results of comparison of original and sweep-twist blades show that sweep-twisting the blade against the direction of rotation causes to decrease in both power output and thrust force. So, the load on the wind turbine tower may be lower if sweep-twist wind turbine blades that are twisted in the leading edge direction and that have same rotor diameters are used. This means that sweep-twist wind turbines blades with larger rotor diameters may be used on same towers that carry original wind turbine rotors.

REFERENCES


A Review of Indoor Localization Use Cases in the Built Environment

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Abstract — Gaining information about the location of a person or an object has become an important issue in the field of built environment as well as industries such as logistics, transportation, manufacturing and healthcare. Location-based services such as on-road navigation, transportation tracking and route monitoring are the motives for a need towards outdoor location detection. In indoor built environments, the importance of localization arises from its value for construction industry in a various range of applications. Detection of building occupancy for automation systems, tracking personnel and equipment for effective management of facilities, providing assets location in construction sites and supporting building emergency response operations are all within the scope of indoor localization. This research aims to validate the need for indoor localization in buildings and to provide a review of indoor localization use cases in the built environment together with the currently available technologies.

Keywords — Indoor localization, building occupancy detection, asset tracking on construction sites, facility maintenance and operations, building emergency response operations

I. INTRODUCTION

Access to location information in outdoors is possible via Global Positioning System (GPS), which is adapted for both military and civil use cases and available to public since early 1980s. Yet, GPS could not be utilized in indoor environments due to the fact that satellite signals are not strong enough to penetrate through the walls [1]. In order to establish a reliable location detection solution in indoor spaces, numerous wireless technologies including radio frequency identification (RFID), wireless local area network (WLAN), ultra-wide band (UWB), and Bluetooth have been studied. However, a convenient and universally accepted solution for sensing locations still does not exist due to the trade-offs between various performance/cost/usability metrics of the currently available technologies. As the performance of indoor localization technologies improve along with the ongoing researches, their utilization in the built environment for various purposes has become an essential issue.

Indoor localization can be defined as the process of identifying the semantic position (such as a room number) of a person or an object in an indoor environment. Location detection in indoors is of great value for architecture, engineering and construction industry. Localization technologies can be used in buildings for various purposes including building occupancy detection, automated asset tracking in construction sites, supporting facility maintenance and operations, and guiding people in building emergency response operations. This paper aims to investigate the need for indoor localization technologies in the built environment and provide a review of localization use cases in buildings.

II. USE CASES OF INDOOR LOCALIZATION IN BUILT ENVIRONMENTS

In this section of the paper, a review of indoor localization use cases will be presented.

A. Building Occupancy Detection

Reducing CO2 emissions by 20% over 1990 values, and increasing renewable energy use by 20% by the year 2020 were put as future objectives for ‘20-20-20 targets’ by the European Commission [2]. Since buildings use 40% of total energy in the world, nearly-zero energy buildings should be the only choice for built environments in the future. Benezeth, et al. [3] listed three solutions for economizing energy consumption, which are utilizing renewable energy sources, providing passive solutions like insulation, and managing the active energy consumption in buildings. It is indicated that reliable building occupancy information is a prerequisite for the third solution. However, a massive part of the large building stock in today’s world are usually operated by energy-wise inefficient building management systems that function based on fixed schedules and do not take crucial factors like presence of people as an input for their operations. Presence and behaviours of people influence the demands for facility operations and increase the energy consumption in buildings [4]. For example, a space’s ventilation and cooling load that represent the amount of fresh air to be supplied to that particular space to maintain good air quality and thermal comfort is affected by the number of occupants in that space zone. Consequently, developing solutions for operating facility services like heating, cooling, air conditioning, and lighting in an occupancy-based demand driven manner has been the topic for many researches in the recent years.

In the current approach of the industry, demand-driven facility services are operated through relying on assumption models and pre-defined occupancy profiles. There are various occupancy assumption models such as the model proposed by
the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) which includes the definition of several occupancy profiles for office building day types [5].

Yet, considering the excessive uncertainty in the nature of occupancy and unpredictable variations over numerous time-scales, it can be deduced that fixed occupancy profiles for buildings are not reliable and real-time monitoring is necessary to gain instant occupancy information. Erickson, et al. [6] emphasize the inefficiency of relying on maximum occupancy assumptions in their paper and explain the situation in office buildings as:

In general, the approach used is to assume that all rooms are occupied during working hours and not being used during the night. However, it is obvious that this does not maximize energy savings. Rooms are often left empty during part of the day or perhaps are only used semi regularly, e.g. conference rooms. It would be more efficient to only condition rooms during the times that are actually occupied. Using an L-HVAC system, various environmental aspects of room can be controlled for energy savings. Thus, knowledge of occupancy is crucial in order to maximize efficiency of a system (p. 19).

In order to understand the influence of dynamic occupancy information on energy usage, Dong and Andrews [7] simulate energy consumption of an office zone with both static occupancy profiles and dynamic occupancy data. Their research shows that, sensing occupancy in real-time could remarkably reduce the energy consumption to a level of 30%. The definition of occupancy information is made by Li, et al. [8] as “the number and identities of occupants in a thermal zone and the resulting activities from occupant being present” (p.89). Considering the fact that one of the main requirements for an economical energy consumption management in buildings is reliable occupancy information, real-time occupancy detection, i.e. instant localization of people in indoor spaces, may be recognized as an effective solution for operating demand driven facility services.

Particularly in dynamic environments, having real-time occupancy information, including the number of occupants and their locations in the building, as Li, et al. [8] claim, may be very useful both in building energy management and applications areas including security, safety and emergency response. The research of Lo and Novoselac [9] showed that a reduction of 30% in cooling energy consumption is possible with the utilization of occupancy control in an open plan office, through considering occupied and unoccupied zones separately in providing facility services. Furthermore, as Erickson, et al. [10] affirm, the energy consumed for air conditioning annually in an office building can be reduced by 42% through sensing the location of people in the buildings while keeping the comfort standards optimum for occupants.

B. Asset Tracking on Construction Sites

As construction materials and equipment account for almost two-thirds of the total cost in a typical construction project, management of assets on the construction site is a critical task for a successful project completion within a constrained budget and targeted project duration [11]. Although the cost of construction projects may be reduced with a comprehensive asset management strategy on site, currently, building materials, equipment, and workers are located and tracked manually within the large project sites. Due to the complex nature of project management and uncontrollable size of built environments, locating and getting spatial information about building materials manually is a difficult task. As the scale of projects gets larger and buildings become more complex, it becomes even harder to track information related with asset locations and manage supply chain manually. Therefore, providing a real-time localization solution and integrating automation in material management becomes a necessity in construction projects. Bisio, et al. [12] revealed that having location information of building components enhance a considerable efficiency in labour, on account of the fact that workers waste almost one third of their time on searching the positions of the desired resources [11]. Besides, Caron, et al. [1] imply that progress state of projects on the site can be monitored in real-time through localization of construction assets.

Considering the fact that countless number of materials and components go through various stages according to project schedule until the completion of on-site installation in a construction project, there exist a direct relationship between asset management procedure and project performance. The results of ineffective asset management on construction sites such as lost materials, late detection of additional material needs, material deliveries in incorrect sequences and deficiencies in supply chain lead to a reduction of 40% in construction productivity [13]. The primary purpose of asset management is clarified by Song, et al. [14] as to track the availability of construction materials and to provide accurate location information when they are needed by the operation crew. Since manual processes of recording data about the availability and locations of construction components depends on the observations and reporting skills of on-site personnel which is both time-consuming and error prone, there is a huge potential in utilizing identification and localization solutions in construction asset management.
Finding the location of a material, a component or a tool is one of the most essential phases of asset management. Song, et al. [15] state that popularity in the prefabricated components usage in the last fifteen years has made tracking and locating the construction components on the field even more critical for project management. Ergen, et al. [16] indicate that there is a dense circulation process for prefabricated materials within the construction sites from material delivery to installation. Moreover, since most of the components are uniquely produced according to the precise architectural design decisions, each prefabricated asset is required to be identified, located and tracked separately. Due to the just-in-time delivery requirement of prefabricated precast concrete, for example, Ergen, et al. [16] developed their research on integrating a localization solution with the purpose of gaining the position information of precast concrete components quickly and accurately when requested and minimizing human input in the recorded asset data. Similarly, Song, et al. [14] point out that automated localization and tracking solutions are of utmost importance since lots of unique components of piping activity in construction projects go through a number of phases including fabrication, delivery, storage, and installation.

In addition to advantages of localization of assets on construction sites, locating on-site personnel in an accurate and precise manner is also critical for various tasks of project management including workers’ productivity estimation, activity sequence analysis, early detection of travel path conflicts, and providing construction work safety.

C. Facility Maintenance and Operations

Activities related with operation and maintenance, which form the fundamental part of facility management for ensuring the continuity in efficient building functionality, constitute almost 85% of the total lifecycle cost of buildings [17]. The definition of facility maintenance is made by Cotts, et al. [18] as:

The work necessary to maintain the original anticipated useful life of a fixed asset. It is the upkeep of property and equipment. Maintenance includes periodic or occasional inspection, adjustment, lubrication, cleaning (non-janitorial), painting, replacement of parts, minor repairs, and other actions to prolong service and prevent unscheduled breakdown, but it does not prolong the life of the property or equipment or add to its value (p. 408).

Maintenance of a facility indicates the works that are to be realized by the facility management services for both keeping the living and working built environments comfortable for inhabitants and administrating the performance of equipment and assets of the facilities. Two main category of maintenance activities are sorted by Thomas [19] as:

- **Demand Work**: where the client calls in for service, where breakdowns in equipment require repairs and emergency events that affect the facilities department.
- **Preventive Maintenance Work**: where a scheduled program of work maintains the investment in the physical assets for a corporation. These assets may be equipment assets or facility assets (p. 457).

Considering its huge percentage in the lifecycle cost of buildings, there are many researches that have been conducted for optimization of facility maintenance where the primary subject of most studies are related to the utilization of computational support for asset management in built environments. In order to ensure an efficient asset management and facility maintenance optimality, indoor localization systems that provide accurate and precise location information of any intended assets or objects in buildings should be integrated into facility management services.

**TABLE 1: CORE MAINTENANCE ACTIVITIES WITH TIME DATA [20].**

<table>
<thead>
<tr>
<th>CMA</th>
<th>Electrician</th>
<th>Plumber</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time (min)</td>
<td>Ratio (%)</td>
<td>Time (min)</td>
</tr>
<tr>
<td>Get maintenance requests</td>
<td>7</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Locate equipment</td>
<td>114</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>Diagnose</td>
<td>84</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Get tools</td>
<td>40</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Get materials</td>
<td>53</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Repair</td>
<td>471</td>
<td>40</td>
<td>187</td>
</tr>
<tr>
<td>Preventive Maintenance</td>
<td>255</td>
<td>22</td>
<td>161</td>
</tr>
<tr>
<td>Project</td>
<td>19</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Contractor Support</td>
<td>10</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Inspection</td>
<td>46</td>
<td>4</td>
<td>43</td>
</tr>
<tr>
<td>Request collaboration</td>
<td>10</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td>Report findings and progress</td>
<td>16</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Document</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>28</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>173</strong></td>
<td><strong>10</strong></td>
<td><strong>51</strong></td>
</tr>
</tbody>
</table>

Lee and Akin [20] listed the core maintenance activities under two categories and demonstrated the time spent for each activity depending on their observations. According to the outcomes of their research, the main inefficiency in the facility maintenance is caused by localization of equipment, which takes approximately 10% of the total maintenance time. It is possible to make an optimization in facility maintenance and save a remarkable amount of time through utilizing accurate localization solutions.

Throughout the activities for providing maintenance in a facility, finding the location of a problematic asset for a demanded work or identification of an equipment for preventive maintenance is always a prerequisite. It is not significant whether the intended asset or equipment is in line of sight or hidden behind a wall or an object, manual visual search is a highly time consuming action on site for facility management service personnel. Lee and Akin [20] indicate that maintenance activities take more time than they should, due to the difficulty in localization of building equipment. It is even harder to locate a building asset or an equipment in more complex and larger buildings and wasting time by searching manually for finding the accurate location may result in more damage in emergencies. In the time of urgent maintenance requirements in buildings, Primary reason for failure in preventing damage is the lack of ability to locate an out of repair component instantly.

For instance, Ergen, et al. [21] point out that fire valves that are placed in different points in a building, some of which are in non-line of sight and unobservable due to some obstructions, should be checked twice a year by facility management services.
personnel according to the fire regulations. However, it is not easy for workers to notice each separate fire valve in a building and locating a fire valve takes five to ten minutes for an experienced worker; whereas an inexperienced worker spends thirty to sixty minutes for each one. Even an experienced worker may have difficulties in finding a target location in a complex facility layout. What Ergen, et al. [21] emphasize is that facility management services workers might not be willing to perform this time consuming and troublesome maintenance task properly and verification of a complete maintenance for desired assets is very hard. Consequently, it cannot be assumed as reliable to put a check mark on a prescheduled maintenance activity in the current approach. Ergen, et al. [21] clarify that indoor localization has a crucial significance for optimization of facility management activities, and sticking a sensor tag which would give a unique identification code to each fire valve and make the localization of all desired assets possible can be the solution for overcoming this inefficient workflow on site.

There is a significant potential in location sensing solutions for minimizing the time spent for asset searching in facilities and ensuring a more effective maintenance. The information about the locations of building assets is needed at different stages of building lifecycle and indoor localization is a timesaving requirement for the maintenance of facilities. In his article, Wing [22] affirms that the position of water and gas pipes that are either buried under floors or pass through the walls can be determined with localization systems. In their research, Lee and Akin [20] demonstrate that it is possible for facility maintenance activities to be performed in a 12% more time-efficient manner through supporting on-site personnel with instant assets-related and location information.

Apart from tracking the locations of assets such as fire valves, pipes or other building assets, indoor localization can also be beneficial for finding the position of hand tools and equipment in a facility. Goodrum, et al. [23] state that since availability of tools in a facility has an impact on the productivity of maintenance personnel, it is important to develop some strategies for equipment management. What Goodrum, et al. [23] believe is that, contrary to frequent approach of having excessive number of tools in a building for ensuring productivity of workers, which may be described as waste of resources in return, having sufficient number of tools and improving their management on site through indoor localization systems is the right strategy.

D. Building Emergency Response Operations

Emergencies in buildings such as structural collapse, flooding and especially fire can turn into fatal disasters for occupants in the buildings and first responders. Li, et al. [24] state that real-time localization of people can be remarkably beneficial in minimizing severe injuries and enhancing success rate in first-time response in building emergency operations. A recent study composed of interviews with first responder professionals by Li, et al. [25] showed that the location of people were considered as one of the most important information piece that is required in times of fire emergency incidents. Throughout the study, a number of information items were given to responders and a pre-determined procedure was followed in order to reach a classification between all information items. A simplified part of the result drawn was shown in Table 2.

Table 2: Importance of Indoor Localization (Adapted from Li, et al. [25])

<table>
<thead>
<tr>
<th>Stage</th>
<th>Importance</th>
<th>Information Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before arrival to scene</td>
<td>- Building floor plan and orientation</td>
<td>- Building occupancy number and identities of occupants</td>
</tr>
<tr>
<td>- Location of access doors and exits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At emergency scene</td>
<td>- Location of fire in the building, size and duration</td>
<td>- Presence and locations of occupants in the building</td>
</tr>
<tr>
<td>- Location and condition of smoke</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After extinguishing</td>
<td>- Location and condition of deployed and standing by responding units</td>
<td>- Required water flow or foam</td>
</tr>
<tr>
<td>- Location of available areas of refuge, staging areas</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to Li, et al. [26], at an emergency scene, detecting presence and position of occupants is not efficient at all with the current process, in which visual inspections are done from a distance to the site, depending on the observations and estimations of incident commanders. It is pointed out that it would be easier to guide the emergency response team only if real-time location information was accessible for monitoring. The inefficiency of current process and need for localization in building emergency response operations is explained by Li, et al. [27] as:

First responders are the first line of defence when building fire emergencies happen, and one of their foremost important tasks is to search and rescue the people trapped in buildings. First responders usually have little knowledge about the location of trapped building occupants, preventing informed decision-making with regard to search route planning and task force allocation. Instead, first responders have to perform a complete search of indoor spaces where people may be trapped. Such search is mostly blind and not efficient, increasing the chances of fatalities and injuries of trapped occupants (p. 78).

Considering the current situation, Li, et al. [27] implied that utilization of a real-time location detection system could reduce the time spent for rescuing the trapped people in an incident and prevent possible fatal outcomes. As they are subjected to lots of dangers in emergencies due to the difficulty in being oriented in complicated, unfamiliar built environments, the real-time location information of the operation units is also critical [26]. Although the professionalism and skills of incident commanders are important factors in a good emergency management based on available collected information, a successful coordination and decision-making is only possible with real-time location monitoring of on-site units for ensuring their safety and guiding them with the correct routes within the disaster sites. Li, et al. [24] suggested that, those first responder units that are disoriented in dangerous spaces can be noticed and alerted by incident commander through real-time monitoring, and they can be directed to trapped people with navigational directives. In addition, it is asserted in the paper.
that potential dangers can be better detected and prevented by first response units themselves if they are provided with access to their real-time positions accurately on the field.

III. OVERVIEW OF WIRELESS BASED APPROACHES FOR INDOOR LOCALIZATION

Despite the popularity of Global Positioning System (GPS) for locating people and positioning objects in outdoor environments, the system does not work for indoors properly due to attenuation of electromagnetic waves by the walls and obstacles due to obstruction of line of sight between the satellites and receivers. Since radio waves have the capability of penetrating walls, obstacles, and human body, radio frequency based technologies are suitable for indoor localization with their wide coverage area and less hardware necessity.

One of the most popular methods studied for detecting occupancy is RFID based models. What separate RFID from the other sensor technologies is its benefits such as its tags features of having unique identity numbers and light, portable designs, its effectiveness in non-line of sight and longer detection range compared to infrared, ultrasound, and WLAN technologies [28]. Despite the capability of RFID sensor based detection systems to provide comprehensive fine-grained occupancy information for demand driven applications in buildings, it has some limitations such as the multipath effect for signal propagation, changing environments’ negative effects on RSSI, and unwillingness of occupants to wear RFID tags.

In WLAN based location detection models, position of every Wi-Fi compatible mobile device can be determined using existing Wi-Fi infrastructure with the aid of a positioning server. In this application line of sight is not required between access points and the target units [29]. Moreover, the coverage area of a WLAN based localization system is expandable since it can bear additional access points, and any mobile target can be tracked unless it goes out of the covered range. Despite its potential for gaining occupancy information, WLAN based systems have their shortcomings and limitations, such as the negative effects of possible changes (i.e. moving furniture) in the environments on Received Signal Strength (RSS), high initial deployment cost, variations in Wi-Fi signal strength by time and possible interferences with other appliances [30].

Ultra-wideband technology is based on data transmission technique through sending and receiving ultra-short radio pulses. UWB systems have the capability of high accuracy indoor localization with low power consumption even in non-line-of-sight conditions. Since signals transmitted from UWB tags use a wider radio spectrum than the other RF-based tools, it is not affected by the interference of other signals in the environment and it has resistance to multipath effects. In addition, large bandwidth of UWB provides high resolution in both time and location for positioning and tracking, and it is suitable for utilizing positioning techniques including time of arrival and time difference of arrival [30]. There are several studies in the literature for developing an applicable UWB based localization and tracking system, yet there are no widely accepted solutions. Although UWB based location detection models have the highest accuracy and precision (with a location error of 15 cm) among all other indoor localization solutions, a comprehensive receiver-transmitter infrastructure is required and the necessary initial deployment is so expensive that it is not in wide-scale use [30].

Bluetooth is a wireless standard for wireless personal area networks, which has zero dBm maximum power output. Classic Bluetooth was released as a unification tool for computers and other devices, and the main purposes of usage were connecting headsets and cell phones, and enabling file transfer between devices and printers. However, the latest version of Bluetooth, namely Bluetooth Low Energy has a potential to be used in indoor localization. Low cost, high security, low power, small size and unique ID identification for each Bluetooth tag can be listed as the main advantages [29]. In addition, since an embedded Bluetooth module do exist in almost every mobile device in today’s world, this technology can be used as a location detection tool without any extra infrastructure. Even though some researchers investigate the applicability of BLE technology for indoor localization, a comprehensive analysis and technological assessment of this technology do not exist in the literature.

IV. CONCLUDING REMARKS

Indoor localization technologies have become a need in the built environments. Building occupancy detection, automated asset tracking in construction sites, supporting facility maintenance and operations, and guiding people in building emergency response operations are demonstrated as the main use cases at the present time. Apart from reviewed cases, localization can also be utilized for route guiding for people in unfamiliar facilities like airports, convention centres, shopping malls, and hospitals. As the performance metrics of localization technologies are constantly improving with the current studies, there will probably be more utilization areas in buildings, which are not applicable now.

Despite the extensive need for a reliable indoor localization system in the built environment, no current approach was identified to be an extensive solution. Once a globally accepted comprehensive solution is provided for localization in indoors, the wasted energy and resources in both buildings and construction sites can be reduced dramatically. As a results, the goal for having a more sustainable and intelligent built environment can be achieved in the future.

REFERENCES

Energy Analysis for an Air-Conditioning System of a Commercial Aircraft: Case study for Airbus A330

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Abstract—The regulation of temperature, pressure, humidity and oxygen intensity of an aircraft cabin is crucial for the flight conditions of a commercial aircraft. Lack of oxygen, lower temperature and pressure induce some health problems for passengers on board. For this reason, hot and pressurized air supplied from aircraft engine compressor section is conditioned in the air-conditioning packages to present comfortable ambience inside of the aircraft cabin as well as cooling of electric components. In this study, an air-conditioning system of Airbus A330 as a commercial aircraft has been investigated at the altitude of 11000 m for 289 people on board under the flight conditions. At this altitude for the aircraft cruising with 871 km/h (Ma = 0.82), cooling loads of cockpit (crew station), passenger cabin and other appliances needed cooling in the aircraft have been calculated. The parameters affecting the cooling load are mainly temperature, pressure and air intensity of aircraft inside and atmospheric outside. In the calculation of the cooling loads, generated heat and heat loss have been considered. For the generated heat value, heat generation by passengers, cabin crew, illumination systems, other equipment and solar radiation have been assumedly calculated. The heat loss from the aircraft fuselage at 20 °C cabin to the outside of the aircraft at -56.5 °C has been found. Heat transfer to meet the fresh air need inside the aircraft has been taken into account. Finally, the obtained cooling loads are 7.4 kW for the maximum value and 5.1 kW for the minimum value at these aforementioned conditions. The maximum and minimum values have been obtained for the daytime and the night time depending on solar radiation, respectively. In the upcoming study, energy analysis is going to be combined with the exergy analysis and the appropriate air-conditioning system for the optimum energy consumption will be evaluated.

Keywords—Air-conditioning, aircraft, altitude, cooling load, energy analysis

I. INTRODUCTION

Air craft cabin temperature and pressure are very important to be conditioned as the passenger aircrafts cruise at high altitudes and at also various conditions. Due to lower pressure and temperature at higher altitudes, air-conditioning system of aircrafts play an important role for both human health and comfort conditions. For this reason, pressurized and hot air of aircraft engine is evaluated to provide high class air ambient inside of the aircraft cabin. Another case is pressurization of the aircraft cabin and it is very crucial to maintain the optimum pressure level at lower altitudes as the cabin has to be impermeable under any circumstances. With this way, high oxygen density can be supplied to the aircraft cabin through the pressurized air as this a significant step to ensure the air-conditioning for passenger health. In present study, an air-conditioning system of Airbus A330-300 RR Trent 700 as a commercial aircraft has been considered for 289 people on board. It is assumed to be cruised at the altitude of 11000 m (correspondingly 36100 ft) with the speed of 871 km/h. Various studies in the literature could be encountered about the air-conditioning of an aircraft cabin. Hocking (2002) has studied on trends in cabin air quality of commercial aircraft in terms of industry and passenger perspectives. It has been presented that improving the aircraft cabin air quality and the partial pressure of oxygen can be provided for minimal cost [1]. Cakir et al. (2003) have presented a study about air-conditioning system in commercial aircrafts and comfort. They have explained the importance of air-conditioning system as it is not easy to provide comfortable and fast trips at high altitudes [2]. Arslan et al. (2009) have investigated the air-conditioning system of an aircraft and its effect to inner air quality. In their study, Boeing 737-800 has been used and they have stated that the filters, sensors, indicators and the control and maintenance of the equipment are substantial for the air-conditioning system of the aircraft [3]. Dumas et al. (2014) have defined a design methodology for the global thermodynamic performance of an airship cabin for high altitude. A fundamental cabin sizing and energetic performance of cabin thermal insulation have been provided [4]. Chen et al. (2015) have studied on hot air distribution of ship cabin air-conditioning. They have pointed out that the ship cabin air-conditioning formed suitable air distribution for characteristics of variable air volume, big air volume and high air velocity [5]. Oliveira et al. (2015) have evaluated the passive aircraft cooling systems for variable thermal conditions. The fuselage condenser performance has been tested for the temperature range between -30 °C and 50 °C. They have determined that heat removal capacity of the fuselage was more dominant in terms of forced convection acting on all condensers [6]. Yang et al. (2015) have researched on the numerical simulation of aircraft cabin smoke as it is a threat for the flight safety severely. They have analyzed the flow regularity of smoke in the aircraft cabin and also the influence of ventilation on cabin smoke diffusion. It is certain that high level of ventilation could decrease the smoke.
and temperature distributions, effectively [7]. Yao et al. (2015) have examined the flow characteristics and turbulence simulation for an aircraft cabin environment. They have utilized BV2FAM simulation and have theoretically showed that topological structure of flow fields in the cabin was unstable [8]. Zhu et al. (2015) have considered the air distribution with natural convection effect of passengers in an air cabin mockup by using PIV experimental setup. They have observed the interaction between natural convection from the passengers and forced convection from the supply air diffusers. They have measured the air flow jet in a 7-row cabin mockup and have concluded that air jet decay rate was slower with increment of natural convection [9]. Čavka et al. (2016) have dealt with energy efficiency in aircraft cabin environment in the context of safety and design. They have emphasized that cabin air temperature, cabin noise, cabin evacuation time and accident rate were the certain parameters for the consideration of aforementioned issues [10]. The aim of this study is energy analysis for an air-conditioning system of a commercial aircraft in case of Airbus A330.

II. COMPOSITION OF ATMOSPHERE

The mixture of gases that make up the atmosphere of the earth is commonly called air. It is composed principally of 78% nitrogen and 21% oxygen and the remaining 1% is made up of various gases in smaller quantities as shown in Fig. 1. Some of these are important to human life, such as carbon dioxide, water vapor, and ozone. Fig. indicates the respective percentage of the quantity of each gas in its relation to the total mixture [11].

![Fig. 1 The percentage of the various gases that comprise the atmosphere [11]](image)

As altitude increases, the total quantity of all the atmospheric gases reduces rapidly. However, the relative proportions of nitrogen and oxygen remain unchanged up to about 50 miles above the surface of the earth. The percentage of carbon dioxide is also fairly stable. The amounts of water vapor and ozone vary [11].

Nitrogen is an inert gas that is not used directly by man for life processes; however, many compounds containing nitrogen are essential to all living matter [11].

The small quantity of carbon dioxide in the atmosphere is utilized by plants during photosynthesis. Thus, the food supply for all animals, including man, depends on it. Carbon dioxide also helps control breathing in man and other animals [11].

The amount of water vapor in the atmosphere is variable but, even under humid conditions at sea level, it rarely exceeds 5%. Water also occurs in the atmosphere as ice crystals. All forms of water in the atmosphere absorb far more energy from the sun than do the other gases. Water plays an important role in the formation of weather [11].

Ozone is a form of oxygen. It contains three oxygen atoms per molecule, rather than the usual two. Most of the ozone of atmosphere is formed by the interaction of oxygen and the rays of sun near the top of the stratosphere in an area called the ozone layer. This is important to living organisms because ozone filters out most of the sun’s harmful ultraviolet (UV) radiation. Ozone is also produced by electrical discharges, such as lightning strikes. It has a faint odor, somewhat like that of weak chlorine, that may be detected after a thunderstorm. Auroras and cosmic rays may also produce ozone. Ozone is of great consequence to living creatures on earth and to the circulation of the upper atmosphere [11].

III. FLIGHT CONDITIONS

Aircrafts are able to cruise at various flight and climate conditions, successfully. At these conditions, the regulation of temperature, pressure, humidity and oxygen intensity of an aircraft cabin is crucial for a commercial aircraft as many passengers are on board. These parameters tend to change with respect to the cruise altitude as in Table I. It indicates that there is a decrease in temperature while rise in altitudes is observed. Particularly, this decrease is seen for the pressure for increasing altitudes. As mentioned before, the total quantity of all the atmospheric gases goes down swiftly because of increase in altitude values.

<table>
<thead>
<tr>
<th>Altitude</th>
<th>Temperature</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet</td>
<td>°C</td>
<td>milibar</td>
</tr>
<tr>
<td>1000</td>
<td>13.17</td>
<td>977.1</td>
</tr>
<tr>
<td>10000</td>
<td>-4.66</td>
<td>696.8</td>
</tr>
<tr>
<td>20000</td>
<td>-24.57</td>
<td>465.6</td>
</tr>
<tr>
<td>30000</td>
<td>-44.29</td>
<td>300.9</td>
</tr>
<tr>
<td>36100</td>
<td>-56.5</td>
<td>226.2</td>
</tr>
</tbody>
</table>

Heat sources for a passenger are solar radiation, the heat of air supplied by air-conditioning system and the heat released by other passengers. Moreover, inner air temperature is conditioned with the help of air-conditioning system in the aircraft cabin. Inner air temperature is adjustable in range of 18.5 °C and 29.5 °C with respect to the human health and comfort conditions [2]. However, cabin temperature is under effect of static and dynamic situations. Another heat source except the air-conditioning system is due to the passengers. At rest, a person generates heat between 80 - 100 W in terms of...
static situation [2]. On the other hand, dynamic situation includes the motion of passengers on board or power-up, take-off and landing of the aircraft. When relative humidity value is investigated, the maximum altitude for the flight of an aircraft presents nearly same humidity value with the driest region of the world. It is obvious that these conditions can cause illnesses and diseases in terms of human health. Therefore, air-conditioning system of an aircraft cabin is significant for previously stated situations. In addition, less oxygen level is seen at higher altitudes. Especially, lack of oxygen for human health is observed and felt after the altitude of 3000 m [2]. This situation affects negatively the respiratory system of a person. For this reason, it is needed to serve ambient quality equivalent to the sea level conditions and it is named as cabin altitude. In air-conditioning system for aviation applications, there are two alternatives to reduce the cabin altitude. Firstly, it can be done by providing sufficient oxygen level or second way is to increase the air pressure. In aviation, global cabin altitude for a commercial aircraft is 8000 ft (2438 m) and it is limit value for a person to breathe on his/her own without any appliances [2].

IV. AIR-CONDITIONING SYSTEM

There are two types of air conditioning systems commonly used on aircraft. Air cycle air conditioning is used on most turbine-powered aircraft. It makes use of engine bleed air or APU pneumatic air during the conditioning process. Vapor cycle air conditioning systems are often used on reciprocating aircraft. This type system is similar to that found in homes and automobiles. It is known that some turbine-powered aircraft also use vapor cycle air conditioning [11]. Air-conditioning system of a commercial aircraft aims following cases such as heating, cooling, equipment cooling, mission cooling, pressurization, distribution and temperature control as indicated in Fig. 2.

![Air Conditioning System Diagram](image1)

As in Fig. 3, the hot compressed air is cooled, conditioned and delivered to the fuselage compartments and then discharged overboard through two outflow valves. Fresh air can also be supplied to the distribution system through two low-pressure ground connections. A ram air inlet supplies emergency air to fuselage if there is a complete failure of the air generation system during flight. A mixing manifold mixes fresh air with cabin air. The cabin air that enters the underfloor area is drawn through recirculation filters by fans. The recirculation fans then blow the air through check valves to the mixing manifold. The flight deck is supplied by fresh air only [13].

Hot bleed air is tapped downstream of the pack valves. The air flows through two hot air valves which control the pressure...
of the hot trim air going into two hot air manifolds. To control the temperature in the different upper deck zones, the quantity of trim air added is controlled through the cockpit and cabin temperature control system [13]. By the way, component locations of an air-conditioning system in the aircraft have been shown in Fig. 4.

Hot air is delivered to air supply ducts through the related zone trim air valves. The trim air valves are controlled through the temperature requirements of each zone and duplicated for cabin zone flexibility. The trim air system has several features to ensure that no substantial comfort degradation occurs in case of trim air valve or hot air valve failure; a hot cross-bleed valve is installed between the hot air manifolds and will open to maintain trim air supply to all rise ducts in the event of hot air failure (blocked open). Moreover, in the event of trim air failure (blocked open) and/or duct overheat, as the shut-off valve is normally closed and there are two riser ducts per cabin zone, only half of each zone will lose its trim air supply. The flight deck is permanently supplied by a constant restricted trim air flow in addition to the normal controlled trim air supply [13].

Fig. 4 Component locations of an air-conditioning system in the aircraft [11]

Heat is an expression of energy, typically measured by temperature. The higher the temperature of a substance, the more energy it contains. Heat always flows from hot to cold. These terms express the relative amount of energy present in two substances. They do not measure the absolute amount of heat present. Without a difference in energy levels, there is no transfer of heat energy [11].

Adding heat to a substance does not always raise its temperature. When a substance changes state, such as when liquid changes into a vapor, heat energy is absorbed. This is called latent heat. When a vapor condenses into a liquid, this heat energy is given off. The temperature of a substance remains constant during its change of state. All energy absorbed or given off, the latent heat is used for the change process. Once the change of state is complete, heat added to a substance raises the temperature of the substance. After a substance changes state into a vapor, the rise in temperature of the vapor caused by the addition of still more heat is called superheat [11].

The temperature at which a substance changes from a liquid into a vapor when heat is added is known as its boiling point. This is the same temperature at which a vapor condenses into a liquid when heat is removed. The boiling point of any substance varies directly with pressure. When pressure on a liquid is increased, its boiling point increases, and when pressure on a liquid is decreased, its boiling point also decreases. Vapor pressure is the pressure of the vapor that exists above a liquid that is in an enclosed container at any given temperature. The vapor pressure developed by various substances is unique to each substance [11].

A. Air Cycle Air-Conditioning

Air cycle air-conditioning prepares engine bleed air to pressurize the aircraft cabin as seen in Fig 5. The temperature and quantity of the air must be controlled to maintain a comfortable cabin environment at all altitudes and on the ground. The air cycle system is often called the air conditioning package or pack. It is usually located in the lower half of the fuselage or in the tail section of turbine-powered aircraft [11].

Fig. 5 Air cycle air-conditioning [11]

Even with the frigid temperatures experienced at high altitudes, bleed air is too hot to be used in the cabin without being cooled. It is let into the air cycle system and routed through a heat exchanger where ram air cools the bleed air. This cooled bleed air is directed into an air cycle machine. There, it is compressed before flowing through a secondary heat exchange that cools the air again with ram air. The bleed air then flows back into the air cycle machine where it drives an expansion turbine and cools even further. Water is then removed and the air is mixed with bypassed bleed air for final temperature adjustment. It is sent to the cabin through the air distribution system. By examining the operation of each component in the air cycle process, a better understanding can be developed of how bleed air is conditioned for cabin use [11].
Most cabin temperature control systems operate in a similar manner. Temperature is monitored in the cabin, cockpit, conditioned air ducts, and distribution air ducts. These values are input into a temperature controller, or temperature control regulator, normally located in the electronics bay. A temperature selector in the cockpit can be adjusted to input the desired temperature. The temperature controller compares the actual temperature signals received from the various sensors with the desired temperature input. Circuit logic for the selected mode processes these input signals. An output signal is sent to a valve in the air cycle air conditioning system. This valve has different names depending on the aircraft manufacturer and design of the environmental control systems (i.e., mixing valve, temperature control valve and trim air valve). It mixes warm bleed air that bypassed the air cycle cooling process with the cold air produced. By modulating the valve in response to the signal from the temperature controller, air of the selected temperature is sent to the cabin through the air distribution system. [11].

Cabin temperature pickup units and duct temperature sensors used in the temperature control system are thermistors. Their resistance changes as temperature changes. The temperature selector is a rheostat that varies its resistance as the knob is turned. In the temperature controller, resistances are compared in a bridge circuit. The bridge output feeds a temperature regulating function. An electric signal output is prepared and sent to the valve that mixes hot and cold air. On large aircraft with separate temperature zones, trim air modulating valves for each zone are used. The valves modulate to provide the correct mix required to match the selected temperature. Cabin, flight deck, and duct temperature sensors are strategically located to provide useful information to control cabin temperature [11].

B. Vapor Cycle Air-Conditioning

The absence of a bleed air source on reciprocating engine aircraft makes the use of an air cycle system impractical for conditioning cabin air. Vapor cycle air conditioning is used on most non-turbine aircraft that are equipped with air conditioning. However, it is not a source of pressurizing air as the air cycle system conditioned air is on turbine powered aircraft. The vapor cycle system only cools the cabin. If an aircraft equipped with a vapor cycle air conditioning system is pressurized, it uses one of the sources discussed in the pressurization section above. Vapor cycle air conditioning is a closed system used solely for the transfer of heat from inside the cabin to outside of the cabin. It can operate on the ground and in flight. This cycle has been shown in Fig. 6 [11].

In the theory of refrigeration, energy can be neither created nor destroyed; however, it can be transformed and moved. This is what occurs during vapor cycle air conditioning. Heat energy is moved from the cabin air into a liquid refrigerant. Due to the additional energy, the liquid changes into a vapor. The vapor is compressed and becomes very hot. It is removed from the cabin where the very hot vapor refrigerant transfers its heat energy to the outside air. In doing so, the refrigerant cools and condenses back into a liquid. The refrigerant returns to the cabin to repeat the cycle of energy transfer [11].

V. APPROXIMATE ENERGY ANALYSIS

In this study, energy analysis for an air-conditioning system of Airbus A330-300 RR Trent 700 as a commercial aircraft has been performed for 289 people on board. It has been indicated in Fig. 7. Even though the maximum speed of the aircraft is 913 km/h, it is assumed to be cruising at the altitude of 11000 m (correspondingly 36100 ft) with a speed of 871 km/h. In the calculation of the cooling loads, generated heat and heat loss have been considered. For the generated heat value, heat generation by passengers, cabin crew, illumination systems, other equipment and solar radiation have been assumedly calculated. The heat loss from the aircraft fuselage at $T_{\text{cabin}} = 20 \, {^\circ}\text{C} (293.15 \, \text{K})$ cabin to the outside of the aircraft at $T_{\text{surface}} = -56.5 \, {^\circ}\text{C} (216.65 \, \text{K})$ has been found.

![Fig. 6 Vapor cycle air-conditioning [11]](image)

Mach number (Ma) for the flight conditions has been calculated with respect to Eq. (1):

\[
\text{Mach number } (\text{Ma}) = \frac{V}{a} = \frac{V}{\sqrt{\gamma R T_0}}
\]
Ma = \frac{V}{c} \tag{1}

Here, “V” symbolizes the aircraft speed and “c” stands for the speed of sound. For the aircraft, the cruise speed is \(V = 871\ \text{km/h}\) (correspondingly \(V = 241.94\ \text{m/s}\)). The speed of sound \(c\) is calculated by Eq. (2):

c = \sqrt{k R T} \tag{2}

In the equation, “k” is the heat capacity ratio and equals to \(k_{air} = 1.4\) for air. “R” is the specific gas constant and its value for air is \(R_{air} = 287\ \text{J/kgK}\). In the formula, \(T\) is \(T_{surface} = 216.65\ \text{K}\) for the outside of the aircraft. According to Eq. (2), the speed of sound has been found to be \(c = 295.04\ \text{m/s}\). After obtaining the speed of sound, Mach number in this condition has been determined as \(Ma = 0.82\) by Eq. (1). It is subsonic flow as \(Ma = 0.82 < 1\).

Heat transfer area for Airbus A330-300 RR Trent 700 has been obtained with respect to Eq. (4) and it has been found to be \(A = 1128.5\ \text{m}^2\).

\[
\Delta T = T_{cabin} - T_{surface} \tag{5}
\]

In Eq. (5), the temperature of the cabin is \(T_{cabin} = 20\ \degree\text{C}\) (293.15 K) and the outside temperature of the aircraft is \(T_{surface} = -56.5\ \degree\text{C}\) (216.65 K). Temperature difference \((\Delta T)\) has been considered by Eq. (5) and it is \(\Delta T = 76.5\ \degree\text{C}(76.5\ K)\).

\[
Q_{loss} = U A \Delta T \tag{6}
\]

In this situation, heat loss has been calculated by Eq. (6) and it has been found to be \(Q_{loss} \cong 25.9\ \text{kW}\) for the aforementioned case. After the heat loss has been evaluated, the next step is to calculate the heat generated in the aircraft. As it was mentioned before, a person generates heat between 80 – 100 W in terms of static situation. It has been assumed to be average 80 W of the heat generated per capita. Heat generated by people on board has been calculated with respect to Eq. (7):

\[
\dot{Q}_{people} = \text{(Number of people)} \times (\text{Heat gen. per capita}) \tag{7}
\]

Here, the number of people on board is 289 and average heat generation per capita is 80 W. The result has been obtained as \(\dot{Q}_{people} = 23.12\ \text{kW}\). Heat generation by the devices of the aircraft has been taken as \(\dot{Q}_{devices} = 2\ \text{kW}\).

For the lighting, there are 50 fluorescent lamps with 12 W for each and 150 fluorescent lamps with 35 W. Heat generation due to the lighting:

\[
\dot{Q}_{lighting} = \sum [(\text{Number of lamps}) \times (\text{Power of each one})] \tag{8}
\]

It has been obtained as \(\dot{Q}_{lighting} \approx 5.85\ \text{kW}\) by using Eq. (8) for the calculation.

In case the glass transmissivity is 40%, solar radiation acting on the glass area of \(A_{glass} = 8.31\ \text{m}^2\) has been calculated by Eq. (9) and total solar irradiance (TSI) has been taken into account as 700 W/m².

\[
\dot{Q}_{radiation} = \text{(Area)} \times \text{(Total solar radiance)} \tag{9}
\]

Here, \(\dot{Q}_{radiation}\) has been obtained for the glass transmissivity value of 100% and then calculated for %40 transmissivity as \(\dot{Q}_{radiation} \approx 2.33\ \text{kW}\) for these conditions.

Total heat generation has been found by using Eq. (10):

\[
\dot{Q}_{generated} = \dot{Q}_{people} + \dot{Q}_{devices} + \dot{Q}_{lighting} + \dot{Q}_{radiation} \tag{10}
\]

With respect to Eq. (10), \(\dot{Q}_{generated} \approx 33.3\ \text{kW}\) has been obtained for the daytime as it includes \(\dot{Q}_{radiation} \approx 2.33\ \text{kW}\). On the other hand, \(\dot{Q}_{generated} \approx 31\ \text{kW}\) has been calculated for the night time excluding \(\dot{Q}_{radiation}\) in the calculation.

### TABLE III

**MATERIALS USED IN THE FUSELAGE OF THE AIRCRAFT**

<table>
<thead>
<tr>
<th>Material (With thickness)</th>
<th>Thermal conductivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner coatings (L₁ = 0.002 m)</td>
<td>λ₁ = 1.4 W/mK</td>
</tr>
<tr>
<td>Honeycomb (L₂ = 0.015 m)</td>
<td>λ₂ = 0.02 W/mK</td>
</tr>
<tr>
<td>Insulation material (L₃ = 0.1 m)</td>
<td>λ₃ = 0.04 W/mK</td>
</tr>
<tr>
<td>Outer shell (L₄ = 0.0015 m)</td>
<td>λ₄ = 120.08 W/mK</td>
</tr>
</tbody>
</table>

In the fuselage of the aircraft, used materials have been indicated with the thickness value (L) in Table II. Moreover, thermal conductivity values (λ) for these materials have been presented. Inner heat transfer coefficient has been assumed to be \(\alpha_{inner} = 12\ \text{W/m}^2\text{K}\) and outer heat transfer coefficient has been considered as \(\alpha_{outer} = 300\ \text{W/m}^2\text{K}\) for the flight conditions.

\[
\frac{1}{U} = \frac{1}{\alpha_{inner}} + \frac{L₁}{λ₁} + \frac{L₂}{λ₂} + \frac{L₃}{λ₃} + \frac{1}{λ₄} + \frac{1}{\alpha_{outer}} \tag{3}
\]

Overall heat transfer coefficient \(U\) has been calculated by Eq. (3) and it has been found to be \(U = 0.3\ \text{W/m}^2\text{K}\).

\[
A = \pi DL \tag{4}
\]

Here, and the diameter of the fuselage is \(D = 5.67\ \text{m}\) as in Fig. 8 while the length of the fuselage is \(L = 63.69\ \text{m}\).

Fig. 8 Cross-sectional area of Airbus A330-300 RR Trent 700 [13]
After calculating the heat generation values for both the daytime and the night time separately, cooling loads provided by the air-conditioning system have been attained by using Eq. (11):

\[
Q_{cooling} + Q_{generated} = Q_{loss}
\]

(11)

Here, \( Q_{cooling} \approx -7.4 \text{ kW} \) as a maximum value has been evaluated for the daytime including the solar radiation. Besides, \( Q_{cooling} \approx -5.1 \text{ kW} \) as a minimum value has been calculated for the night time excluding the solar radiation. The negative sign in front of the cooling load shows that air-conditioning system works in the aircraft.

VI. CONCLUSIONS

The adjustment of temperature, pressure, humidity and oxygen intensity of the aircraft cabin is important when the flight conditions of a commercial aircraft are taken into account. Health problems especially for passengers on board could be seen due to adverse conditions. That is why; hot and pressurized air obtained from aircraft engine compressor zones is conditioned in the air-conditioning system to present comfortable ambience inside of the aircraft cabin. In present study, an air-conditioning system of Airbus A330 has been examined at the cruise altitude of 11000 m for 289 people on board. At this altitude for the aircraft cruising with 871 km/h (Ma = 0.82), cooling loads of cockpit (crew station), passenger cabin and other appliances required cooling in the aircraft have been obtained. The effective parameters on cooling load have been determined as temperature, pressure and air density of aircraft inside and atmospheric outside. In the calculation of the cooling loads, generated heat and heat loss have been considered. For the generated heat value, heat generation by passengers, cabin crew, illumination systems, other equipment and solar radiation have been assumedly calculated. The heat loss from the aircraft fuselage at 20 °C cabin to the outside of the aircraft at -56.5 °C has been found. To sum up, obtained cooling loads are 7.4 kW for the maximum value and 5.1 kW for the minimum value at these aforementioned conditions in terms of the daytime and night time depending on solar radiation, respectively. These maximum and minimum values have been attained with the negative sign in front of their values and it indicates that air conditioning system of this aircraft operates successfully under considered conditions.

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REFERENCES

DETERMINATION OF VIBRATION CHARACTERISTICS ON VERTICAL AXIS OF A FOUR CYLINDER GASOLINE ENGINE

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Abstract—The vibration characteristics on the vertical axis of a four cylinder 1.4 L Otto engine was investigated under partial throttle opening rates and different engine speeds, in the study. In the first part of the study, vibration measurements were made in terms of acceleration on the top of engine block. The vibration data were determined in 5 partial throttle opening rates and for 4 engine speed as RMS (Root mean square) and illustrated with graphs. With polynomial regression method, the characteristics equations for each throttle opening have been formed. In the second part, the measurements were made by changing engine speeds for each throttle opening and the obtained results were compared with the results determined from the equations.

Keywords—Engine Vibration, Polynomial Regression, Throttle Rate, Root Mean Square, Engine Speed

I. INTRODUCTION

In the internal combustion engines, the vibrations occur due to the motions of rotating, oscillating and linear moving parts. The engine block that mounted on the chassis periodically vibrates because of inertia forces and gas pressure forces [1,2]. The chassis vibration acts on the driver and passengers. So, the engine vibration must be kept under control. In recent years, there have been a lot of studies on the engine vibrations.

Öztürk and Karabulut have investigated the engine block vibrations of a one cylinder - four stroke diesel engine. They made a dynamical model of the piston, connecting rod, crankshaft and the engine block. The model was four degree of freedom system that includes the rotational motion of the crank, the rotational motion of the engine block with respect to the crank axis, horizontal and vertical linear motions of the block. In the analysis, it was determined that the block vibrations with respect to the crank axis are caused by gas forces and the vertical and horizontal vibrations are caused by piston mass and the unbalance of the crank [3].

In a study by Barelli at al., it has been detected that the most powerful vibration signals can be measured on the cylinder head depending on the engine load and combustion frequency in the internal combustion engines [4].

In the other study, Manieniyan and Sivaprakasam used diesel and the bio-diesel derived from mahu as a fuel, respectively. The vibration data as acceleration were measured from the cylinder head, bottom of the engine and crank bearings. The largest amplitude on the cylinder head has been detected when using bio-diesel. In the other points, the largest amplitudes have been obtained when using diesel [5].

Wongchai et al. have investigated the effects of the hydrogen-diesel blend on the engine vibration. Second order polynomial regression analyses were made to find a correlation between the percentage of hydrogen fuel and vibration amplitude. As a result of the study, it has shown that in response to increasing amounts of hydrogen, engine vibration amplitude decreases [6].

II. MEASUREMENT OF THE VIBRATION

In order to acquire the vibration data, Honda L13A i-DSI engine was used in the experiments as a test engine. This spark ignited gasoline engine has 4 cylinders, 1.4lt volume and the compression ratio is 10.8.

The test engine runs on a platform that is fixed the floor with the other parts of the setup (dynamometer, radiator, cooling water tank, fuel tank, battery etc.) schematic representation of the test engine and all setup is shown in Fig. 1.

Fig.1 Schema of the setup

A computer with a data acquisition card, signal conditioner, connector block and accelerometer was used for measuring the vibration. The top of the first cylinder head were selected
for vertical axis vibration measurements and the accelerometer was mounted on it.

The vibration amplitudes have been determined as acceleration in terms of m/s² in the tests and the each measurement lasted 5 s. The values were measured with varying engine speed, while the throttle rate was fixed.

In the first part of the experiments, the vibration data were obtained in 10%, 20%, 30%, 40% and 50% throttle opening rates and for 1400, 2000, 3000 and 4000 RPM engine speeds.

Amplitude - time for 10% throttle rate is shown in figure 3. The vibration levels can be seen on the graph for 4 different engine speeds simultaneously. The amplitude changings in response to varying engine speed can be realized easily.

Determinations of root mean square (RMS) values instead of vibration levels provide great convenience to find characteristic data. RMS values are calculated as:

\[
X_{RMS} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} x_i^2}
\]  

(1)

RMS values were calculated by using Matlab program and the obtained results have been given in figure 4 for each throttle opening ratios.

III. DETERMINATION OF CHARACTERISTIC EQUATIONS OF EACH CURVE

In figure 4, it can easily be seen that all curves are almost parabolic curves. If these curves can be defined with quadratic equations, it enables to find not only relationship between engine speed and vibration amplitude but also intermediate values on the graphs.

In the study, polynomial regression method was applied to find the equations of the curves. The equations have been determined by Matlab program practically. The equations are shown in table 1. In the table, x values correspond to engine speed values.

<table>
<thead>
<tr>
<th>THROTTLE OPENING RATE</th>
<th>EQUATION</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>5.41 \times 10^{-6} \cdot x^2 - 3.41 \times 10^{-5} \cdot x + 4.27</td>
<td>0.9999</td>
</tr>
<tr>
<td>20%</td>
<td>5.59 \times 10^{-5} \cdot x^2 - 7.63 \times 10^{-4} \cdot x + 12.76</td>
<td>0.9994</td>
</tr>
<tr>
<td>30%</td>
<td>7.36 \times 10^{-4} \cdot x^2 - 1.37 \times 10^{-3} \cdot x + 16.87</td>
<td>0.9999</td>
</tr>
<tr>
<td>40%</td>
<td>9.76 \times 10^{-3} \cdot x^2 - 2.49 \times 10^{-2} \cdot x + 30.56</td>
<td>0.9978</td>
</tr>
<tr>
<td>50%</td>
<td>1.36 \times 10^{-2} \cdot x^2 - 4.56 \times 10^{-2} \cdot x + 50.74</td>
<td>0.9837</td>
</tr>
</tbody>
</table>

In the second part of the study, the measurements were made by changing engine speeds as 200 by 200 from 1400 to 4000 Rpm for each throttle ratio. The obtained results were compared with the results determined from the equations separately.

For all throttle rates, the comparison graphs are shown below in figure 5-9.
Main concluding remarks are as follows:

- The experimental study indicates that the vertical axis vibration amplitudes increase in response to increasing engine speed for all throttle rates.
- It is shown that the curve fitting techniques especially polynomial regression is applicable for estimating the intermediate vibration values of the engine.
- The fitted curves for all throttle opening rates are very close to the experimental curves.
- The coefficient of determination ($R^2$) values are more than 0.98.
- Generally, the difference between the values (obtained from fitted curve and experimental results) is less than 10% and maximum error is 6 m/s$^2$.

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Energy Import Dependency And Seeking For New Energy Technologies
European Union Case
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Abstract— In this paper, energy poverty and as a result of this energy import dependency and its possible negative results have been examined by taking European Union (EU) into consideration. This analysis has two aims: the first one is questioning the European Unions’ energy security from supply perspective and the second one is investigating the solutions produced by European Union to get away or at least to reduce its energy import dependency. To guarantee its energy supply security at affordable price and to attain its targets about energy security, some action plans has being put into practice at energy technologies by the Union, especially about renewable energy technologies and energy efficiency. By analyzing them this study aims to give a perspective for other energy dependent countries such as Turkey. Because, as an import depended country at energy, Turkey has same supply security risks with European Union. Modeling the strategies developed and experienced by the EU at renewable energy and energy efficiency, to cope with energy import dependency, might give Turkey an opportunity to minimize drawbacks of its own import dependency problem.

Keywords— Energy Security, European Union, Strategic Energy Technology Plan, Renewable Energy, Energy Efficiency

1. INTRODUCTION

Today, for all countries in the world, to sustain development, one of the most important instruments is energy security. It is because of, without maintained energy supply, there are no electricity, heating, transportation and industrial production, which means no life for modern society. According to International Energy Agency (IEA), which established after a very serious energy supply security crises in 1974, after Yom-Kippur War, energy security is the uninterrupted availability of energy sources at an affordable price. For the Agency, long-term energy security mainly deals with timely investments to supply energy in line with economic developments and sustainable environmental needs. Short-term energy security focuses on the ability of the energy system to react promptly to sudden changes within the supply-demand balance [1]. At this point defining energy sources which are subject of energy security is crucial since lack of energy security is defined by giving priority to oil and natural gas. Oil and natural gas are principal conventional energy sources with coal. Their physical availability and pricing mechanism makes them subject of energy security in general for energy poor regions and countries such as the European Union. [2]

During last fifty years some energy crisis were seen in the world mostly because of regional wars at the Middle East. As outcomes of the oil crises of the 1970s and 1980s, oil price increased as a result of petroleum embargo of oil rich and exporter Arab governments [3]. Today, scarcity of fossil fuels is not just because of any political or military crises. Its because reserves of oil, natural gas and coal are running out while demand is globally increasing. Only coal reserves still appears to be sufficient longer than oil and gas as seen at Fig. 2 [4]. However, turning back to coal includes some other security questions about climate change, which could play an important role at rising global CO2 emission.

<table>
<thead>
<tr>
<th>YEARS</th>
<th>1995</th>
<th>2005</th>
<th>2014</th>
<th>2015</th>
<th>REMAINING</th>
</tr>
</thead>
<tbody>
<tr>
<td>COAL (Million Ton)</td>
<td>......</td>
<td>......</td>
<td>89115.31</td>
<td>114 YEARS</td>
<td></td>
</tr>
<tr>
<td>NATURAL GAS (Trillion Cubic Meters)</td>
<td>119.9</td>
<td>157.3</td>
<td>187.0</td>
<td>166.9</td>
<td>52.8 YEARS</td>
</tr>
<tr>
<td>OIL (Thousand Million Barrels)</td>
<td>1126.2</td>
<td>1374.4</td>
<td>1700.0</td>
<td>1697.6</td>
<td>50.7 YEARS</td>
</tr>
</tbody>
</table>

Fig. 1. International Energy Agency Energy Security Scheme

Fig. 2. Remaining Coal, Natural Gas and Oil Reserves in the World (2015)
The extent of the problem is not restrictable just with coming source shortage and climate issues. The remaining oil and gas reserves are concentrated in politically unstable countries and regions. If big consumer countries and regions cannot be successful at energy saving, efficiency and renewable energy policies, etc. it could be a real threat for their energy supply security and everything about maintain existence of their well-fare and economic development, which are related to it.

As one of the most developed region in the world, EU has been having problems at providing its energy security because of the big gap between the Unions energy consumption and energy production from fossil fuels. That makes the EU fragile to energy supply interruptions because of any reason and price volatility at energy market where producer countries have advantage against supplier countries. To cope with this problems and get its own energy security the Union has been being made investments and supported renewable energy projects as indigenous clean energy and additionally put into practice energy efficiency policy. Especially for last ten years the Union has gave momentum to his achievements to be successful at its energy security strategy. To understand this process, in this study first we are going to examine the energy outlook of the Union and then, as an example to energy technology action plans to the EU, Strategic Energy Technology Plan, in short SET-Plan, is going to be explained.

II. EUROPEAN UNION ENERGY OUTLOOK

Throughout the introduction, some aspects about energy security has been mentioned like, energy scarcity or poverty, unfair distribution of the rest of energy sources in the world, energy supply security and getting energy at affordable price, etc. To understand all those facts properly, first, we are going to set light to world energy outlook by some figures from IEA, European Commission and BP. After that, under light of all those information we are going to take a picture of, energy outlook of the EU to understand main problems about its energy security.

According to, International Energy Agency “World Energy Outlook 2014” by 2040, the world’s energy supply mix divides into four almost-equal parts: oil, gas, coal and low-carbon sources as seen at Figure 3. [5]

The world’s energy resources are plentiful and capable of meeting energy demand far beyond 2040; but many are also dispersed unevenly and they are not all inexhaustible as seen at Figure 2. While the assessed abundance of energy resources seldom changes dramatically from one year to the next, the circumstances surrounding their successful exploitation never stand still. [6]

According to BP, primary energy consumption is getting slower when we focus on per annum (p.a.) on the other hand cumulative demand growth says something else, at which %41 increment is expected between 2012 and 2035. [7] To cope the demand growth, 900 billion dollars is needed per year in upstream oil and gas development by the 2030s.

Investment of some $900 billion per year in upstream oil and gas development is needed by the 2030s although there are many uncertainties over whether this investment will be forthcoming in time. Here many obscurities could count. For example, the production of tight oil level starts to fall back in United States. Tight oil output levels off in the early 2020s and its total production eventually starts to fall back. The situation of Brazilian deep-water fields and Canadian oil sands output are still a conundrum. The sanctions that restrict Russian access to technologies and capital markets and – above all – the political and security challenges in Iraq could all contribute to a shortfall in investment below the levels required. The situation in the Middle East is a major concern given steadily increasing reliance on this region for oil production growth, especially for Asian countries that are set to import two out of every three barrels of crude traded internationally by 2040 [8].

![Fig. 3. Energy consumption by fuel between 1965-2035 and ten year increments by fuel between 1975-2035](image)

As seen at Fig. 4 [9] at the end of 2013, 13642 Mtoe energy was produced in the world. The share of petroleum and products is %30.9, solid fuels %29.4, natural gas %21.3, renewables %13.4, nuclear %4.7 and other fuels %0.3 at this production. Almost %33 of the production was made by United States and China, which are also biggest consumers in the world at the end of 2013. For the EU it is not the same.

![Fig. 4. World Energy Production by Region (Mtoe)](image)
Production of primary energy was accounted for by exploitation of limited resources uneconomical. May, at least in part, be attributed to supplies of raw materials downward development of EU in 2014 than it had been a decade earlier. The general economic crisis. When viewed over a longer period, the production in 2009 that coincided with the financial and rebounded following a relatively strong fall in energy.

When we look at Figure 5 [10], the EU is seen as the forth biggest energy consumer region in the world by %12 but according to Figure 4, it produced only %5.8 of the world energy. That means the Union is supplying more than half of its energy by import.

The dependency of the EU on energy imports, particularly of oil and more recently of gas, forms the backdrop for policy concerns relating to the security of energy supplies. Indeed, more than half (53.5 %) of the EU-28’s gross inland energy consumption in 2014 came from imported sources.

Production of primary energy in the EU-28 totalled 771 million tonnes of oil equivalent (Mtoe) in 2014. This continued the generally downward development observed in recent years, with 2010 the main exception as production rebounded following a relatively strong fall in energy production in 2009 that coincided with the financial and economic crisis. When viewed over a longer period, the production of primary energy in the EU-28 was 17.3 % lower in 2014 than it had been a decade earlier. The general downward development of EU-28 primary energy production may, at least in part, be attributed to supplies of raw materials becoming exhausted and/or producers considering the exploitation of limited resources uneconomical. [11]

In 2014, close to one quarter (25.5 %) of the EU-28’s total production of primary energy was accounted for by renewable energy sources, while the share for solid fuels (19.4 %, largely coal) was just below one fifth and the share for natural gas was somewhat lower (15.2 %). Crude oil (9.1 %) was the only other major source of primary energy production.

The growth of primary production from renewable energy sources exceeded that of all the other energy types; this growth was relatively uniform during the period covering 2004–14, with a small dip in production in 2011 as seen at Figure 6. [12] Over this 10 year period the production of renewables increased by 73.1 %. By contrast, the production levels for the other primary sources of energy generally fell over this period, the largest reductions being recorded for crude oil (-52.0 %), natural gas (-42.9 %) and solid fuels (-25.5 %), with a more modest fall of 13.1 % for nuclear energy. [13]

The use of renewable energy has many potential benefits, including a reduction in greenhouse gas emissions, the diversification of energy supplies and a reduced dependency on fossil fuel markets (in particular, oil and gas). The growth of renewable energy sources may also have the potential to stimulate employment in the EU, through the creation of jobs in new ‘green’ technologies. [14]

In the EU, renewable energy sources include wind power, solar power (thermal, photovoltaic and concentrated), hydroelectric power, tidal power, geothermal energy, biofuels and the renewable part of waste. Among renewable energies, the most important source in the EU-28 was solid biofuels and renewable waste, accounting for just under two thirds (63.1 %) of primary renewables production in 2014. Hydropower was the second most important contributor to the renewable energy mix (16.5 % of the total), followed by wind energy (11.1 %). Although their levels of production remained relatively low, there was a particularly rapid expansion in the output of wind and solar energy, the latter accounting for a 6.1 % share of the EU-28’s renewable energy produced in 2014, while geothermal energy accounted for 3.2 % of the total. There are currently very low levels of tide, wave and ocean energy production, with these technologies principally found in France and the United Kingdom. [15]
The latest information available for 2014 (see Fig.7) shows that electricity generated from renewable energy sources contributed more than one quarter (27.5\%) of the EU-28’s gross electricity consumption. [16] In Austria (70.0\%) and Sweden (63.3\%) at least three fifths of all the electricity consumed was generated from renewable energy sources, largely as a result of hydropower and solid biofuels.

The growth in electricity generated from renewable energy sources during the period 2004 to 2014 (see Fig. 6) largely reflects an expansion in three renewable energy sources, namely, wind turbines, solar power and solid biofuels. Although hydropower remained the single largest source for renewable electricity generation in the EU-28 in 2014 (43.9 \% of the total), the amount of electricity generated in this way in 2014 was relatively similar to that recorded a decade earlier, rising by just 12.1\% overall. By contrast, the quantity of electricity generated from solid biofuels (including renewable waste) and from wind turbines in 2014 was 1.8 times and 3.3 times as high as in 2004. The relative shares of wind turbines and solid biofuels in the total quantity of electricity generated from renewable energy sources rose to 27.4 \% and 18.0 \% respectively in 2014. The growth in electricity from solar power was even more dramatic, rising from just 0.7 TWh in 2004 to overtake geothermal energy in 2008, reaching a level of 92.3 TWh in 2014. Over this 10 year period, the contribution of solar power to all electricity generated from renewable energy sources rose from 0.1 \% to 10.0 \%. Tide, wave and ocean power contributed just 0.05 \% of the total electricity generated from renewable energy sources in the EU-28 in 2014. [17]

At the end of 2008, the EU agreed to set a target for each Member State, such that renewable energy sources (including liquid biofuels, hydrogen or ‘green’ electricity) should account for at least 10 \% of all fuel used within the transport sector by 2020. The average share of renewable energy sources in transport fuel consumption across the EU-28 was 5.9 \% in 2014, ranging from highs of 21.6 \% in Finland and 19.2 \% in Sweden (the only Member States with double-digit shares) to less than 1.0 \% in Spain and Estonia. [18]

The share of renewable energy in gross final energy consumption is identified as a key indicator for measuring progress under the Europe 2020 strategy for smart, sustainable and inclusive growth. This indicator may be considered as an estimate for the purpose of monitoring Directive 2009/28/EC on the promotion of the use of energy from renewable sources — however, the statistical system in some countries for specific renewable energy technologies is not yet fully developed to meet the requirements of this Directive; for example, ambient heat energy for heat pumps is not reported by many countries. Furthermore, for the calculation of the share the Directive requires hydropower and wind energy to be normalised to smooth the effects of variations due to weather; given the 15-year normalisation requirement for hydropower production and the availability of energy statistics (for the EU-28, starting from 1990), long time series for this indicator are not available. [19]

On 6 June 2012, the European Commission presented a Communication titled, ‘Renewable energy: a major player in the European energy market’ (COM(2012) 271 final), outlining options for a renewable energy policy for the period beyond 2020. The Communication also called for a more coordinated European approach in the establishment and reform of support schemes and an increased use of renewable energy trading among EU Member States. In January 2014, the European Commission put forward a set of energy and climate goals for 2030 with the aim of encouraging private investment in infrastructure and low-carbon technologies. One of the key targets proposed is for the share of renewable energy to reach at least 27 \% by 2030. These objectives are seen as a step towards meeting the greenhouse gas emissions targets for 2050 put forward in the Roadmap for moving to a competitive low-carbon economy in 2050 (COM (2011) 112 final).

One of the 10 priorities of the European Commission put forward in 2014 is an energy union. It is intended that a European energy union will ensure secure, sustainable, competitive and affordable energy. In February 2015, the European Commission set out its plans for a framework strategy for a resilient energy union with a forward-looking climate change policy in a Communication (COM(2015) 80 final). The Communication proposes five dimensions for the strategy, one of which is decarbonising the economy. [20]

III. EUROPEAN UNION STRATEGIC ENERGY TECHNOLOGY PLAN

The European Strategic Energy Technology Plan (SET-Plan) aims to accelerate the development and deployment of low-carbon technologies. It seeks to improve new technologies and bring down costs by coordinating research and helping to finance projects. The SET-Plan promotes research and innovation efforts across Europe by supporting technologies with the greatest impact on the EU’s transformation to a low-carbon energy system. It promotes cooperation amongst EU countries, companies, research institutions, and the EU itself. The SET-Plan includes the SET-Plan Steering Group, European Industrial Initiatives, the European Energy Research Alliance, and the SET-Plan Information System. [21]

The Integrated SET-Plan identifies 10 actions for research and innovation, based on an assessment of the energy system needs and on their importance for the energy system transformation and the potential to create growth and jobs in the EU;
- Addresses for these actions the whole innovation chain, from basic research to market uptake, both in terms of financing as well as in terms of regulatory framework;
- Adapts the structures set up under the SET-Plan to ensure a more effective interaction with Member States and stakeholders;
- Proposes to measure progress as part of the annual reporting of the State of the Energy Union via overall Key Performance Indicators (KPI’s), such as the level of
investment in R&I, as well as specific KPI’s to measure progress on the performance and cost-reduction for the priorities.

Low-carbon technologies such as photovoltaics, wind power, nuclear fusion or carbon capture and storage are essential to reduce greenhouse gas emissions and improve the sustainability of the energy system. The uptake of new energy technologies can also decrease the Unions reliance on external suppliers of fossil fuels, as well as spur job creation and economic growth. [22]

At the same time, technological investment is often expensive and commercially risky. Energy companies on their own may not deliver technological breakthroughs quickly enough. Public policy and investment, in partnership with the private sector, is therefore necessary to boost the development and deployment of low-carbon technologies for the future. To reach its low carbon energy targets the EU has a foundation programme, Horizon 2020, which is in accordance with SET-Plan targets. [23]

Under circumstances of SET-Plan, 446 project are being waged. For example, Biowalk4Biofuels, HESCAP, BIOCORE, ORECCA, VALORGAS, INTEGRIS, SUPRA-BIO, SUNSTORE, WAVESTAR, CACHET, etc. [24]

IV. CONCLUSIONS

As has been told through the study, conventional fossil fuels are coming to their end. If we take coal to the center, they will not be in the world almost after a century. This time is almost fifty fifty for oil and natural gas. That means as an energy import dependent region, not only the members of the European Union, but also all countries in the world need to be ready for a time without coal, oil and natural gas especially which are already not sufficient itself at fossil fuel sources.

The only problem, which the world will face, is not only energy poverty, related to high carbon technology, the world is also in danger to face with climate change that would be reason of a real catastrophe in the world. The EU has a real awareness about these two upcoming dangers as understood from its energy security policy. By its energy security supply policy, especially 2020 and 2030 renewable targets, the Union is taking measures for both, sustainable and affordable energy supply and reducing carbon emission. To reach its clean and domestic energy targets the EU has lots of programmes, which are supporting financial and political collaboration with other countries. The Unions energy strategy is a good model for other countries in the world. Especially which are energy dependent and fragile to external energy shocks and consume high carbon including energy sources like Turkey. The applications of the EU about renewable energy, smart cities, energy storage etc. need to be followed closely because it contains experience and positive results for other the countries which still does not has an action plan for near future.

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Heat Transfer of Two Phases (Water – Air) in Horizontal Smooth and Ribbed Ducts

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Abstract— Computational fluid dynamics (CFD) was used to investigate the flow of water and air in smooth and ribbed duct. Temperature was applied for the top and the bottom of the duct where the ribs are located. The heat transfer coefficient were calculated at different location inside the ducts and the results was validated using several heat transfer coefficient correlations that was developed by other researchers. Three shapes of ribs was studied which are rectangular, trapezoidal, and triangle. Three water velocities and three air velocities was studied (0.4, 0.6, and 0.8 m/s), and (0.12, 0.15, and 0.18 m/s), respectively. The heat transfer coefficient increased by adding ribs, it also increased as the velocity of the flow increased.

Keywords— Heat transfer, Ribbed duct, Two phase, Ansys Fluent, CFD

1. INTRODUCTION

There are two types of techniques available to increase the heat transfer which are active and passive techniques. Passive techniques include additives of fluid, devices of swirl flow, extended and coated surfaces, and roughed surfaces anything that include applying special surface geometry. Active techniques include vibration of surface, acoustic or electric fields, and mechanical aids simply the techniques that require external power source (Manca O. et al. (2011)). Ducts and pipes that roughed with ribs are widely used in several applications such as ventilation, turbine blades, and heat exchangers (Ansari M. R. et al. (2013)). Ribbed ducts are commonly used for the enhancement of convection heat transfer since the presence of ribs increase the turbulent and produce flow circulation which increase the heat and mass transfer also the thermal boundary layer thickness are reduced by the ribs due to the secondary flow regions that appear near the wall which increase the heat transfer rate (Ansari M. R. and Arzandi B. (2012); Komeil M. et al. (2015)). Several researcher studied the ribbed channels, Song X. O. et al. (1996) compared the trajectories and particle velocities and particle impacts wall wastage by means of rib and smooth welding wall, experimentally and computationally. Both results showed that wall erosion are reduced by adding ribs on wall. Manca O. et al. (2011) Numerically investigated the angle between the ribbed surface and the direction of the fluid flow using three dimensional rectangular ribbed channel model. Ansari M. R. and Arzandi B. (2012) Experimentally investigated the air water two phase flow using ducts that are smooth and ribbed to show the effect of ribs height on the boundaries, they also presented a flow map diagram. Yemenici O. and Sakin A. (2013) Used the finite volume method to investigate the flow of air over heated ribbed wall, they showed that heat transfer are improved by the presence of ribs. Coletti F. et al. (2014) Used the particle image velocimetry two dimensional time resolved to study the turbulent flow within a rotating channel having ribs along one wall. They showed that both the centrifugal force and coriolis force effects the fluid dynamics as the ribbed wall is heated. Boukadoum A. B. and Benzaoui A. (2014) Performed a computational fluids dynamics simulation to analyze the flow and to study the convection heat transfer in solar air heaters duct having rectangular ribs. Komeil M. et al. (2015) Numerically investigated the ribbed tubes convection heat transfer using Al2O3-water nonfluid turbulent flow and different shapes of rib. They showed that its thermodynamically advantageous. Jaiswal S. and Aharwal K. R. (2015) Performed three dimensional numerical study using Ansys fluent to study the fluid flow characteristics and the heat transfer with in ribbed channel. In this work a computational fluid dynamics simulation was performed for a two phase (air-water) flow in ribbed channel. Three rib shapes was used (Rectangular, Trapezoidal, and Triangle) and the results compared with smooth channel to show the effect of ribs on the heat transfer coefficient. The results of the CFD two phase model was validated using heat transfer coefficient correlations that developed by Boyko L. D. and Kruzhilin G. N. (1967), Serizawa A. I. and Michiyoshi I. (1975), Shah M. M. (1981), and Kim D. and Ghajar A. J. (2002). And the results were in good agreement.

2. PROBLEM DESCRIPTION

Ribbed duct with two phase (air – water) flow flowing through it was investigated, figure (1a). Two dimensional geometry model was generated using SolidWorks 2013. The duct consists of a (146 cm) entrance section to insure a fully developed flow and (54 cm) ribbed heated section with (4.5 cm) height. Uniform temperature was applied on the top and bottom of the ribbed section. The inlet of air and water was given a special arrangement, detailed view of the inlet section are shown in figure (1b). Three different shapes of ribs was studied which as (rectangular, trapezoidal, and triangle) as shown in figure (2), smooth duct was also generated to show the difference made by the ribs. The ribs have a base width of (w = 1.5 cm) and height of (e = 0.8 cm) along with a bitch distance of (b = 4.5 cm). Three values of air and water velocities was investigated (0.12, 0.15, and 0.18 m/s), and (0.4, 0.6, and 0.8 m/s), respectively. Table (1) shows the tests that was performed with respect to the water and air velocities for each rib shape and for the smooth duct as well. Ansys
Fluent 15.0 was used to simulate the flow of air-water in a ribbed duct. Two phase mixture model along with the k-epsilon standard turbulent model were used using water as the primary phase and air as the secondary phase.

![Diagram of ribbed duct](image)

**Fig. 1** Problem description (a) The rectangular ribbed duct (b) The inlet section

![Diagram of ribbed duct shapes](image)

**Fig. 2** Ribs shape

**TABLE 1**

<table>
<thead>
<tr>
<th>Test number</th>
<th>Water velocity (m/s)</th>
<th>Air velocity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>0.4</td>
<td>0.12</td>
</tr>
<tr>
<td>Test 2</td>
<td>0.4</td>
<td>0.15</td>
</tr>
<tr>
<td>Test 3</td>
<td>0.4</td>
<td>0.18</td>
</tr>
<tr>
<td>Test 4</td>
<td>0.6</td>
<td>0.12</td>
</tr>
<tr>
<td>Test 5</td>
<td>0.6</td>
<td>0.15</td>
</tr>
<tr>
<td>Test 6</td>
<td>0.6</td>
<td>0.18</td>
</tr>
<tr>
<td>Test 7</td>
<td>0.8</td>
<td>0.12</td>
</tr>
<tr>
<td>Test 8</td>
<td>0.8</td>
<td>0.15</td>
</tr>
<tr>
<td>Test 9</td>
<td>0.8</td>
<td>0.18</td>
</tr>
</tbody>
</table>

2.1. Mesh

Quadrilateral unstructured mesh was performed for the models using Ansys 15.0, the number of elements were (240121, 239009, 243329, and 245875) for rectangular ribbed, trapezoidal ribbed, triangle ribbed, and smooth duct. Three mesh sizes were used to check the mesh dependence and the accuracy of the results. Table (2) shows the number of element for the mesh sizes used. The percentage deviation of the heat transfer coefficient results with several heat transfer correlations are shown as well in table (2), for smooth duct. Figure (3) shows the initial mesh for the three types of ribs.
The equation general form is as \((\text{Guide } 2006)\).

Continuity, momentum and energy for mixture (Fluent User’s velocities. The mixture model solves the equation of flow of water and air in the ribbed duct. This model is used when the phases of a multiphase flow move at different velocities. The mixture model solves the equation of continuity, momentum and energy for mixture (Fluent User’s Guide 2006).

**I. Continuity Equation**

The equation general form is as \((1)\)

\[
\frac{\partial}{\partial t}(\rho_n \overline{u_n}) + \nabla (\rho_n \overline{u_n} \overline{u_n}) = 0
\]  

\text{(1)}

Where \(\overline{u_n}\) and \(\rho_n\) is the mass-averaged velocity and the mixture density, respectively, represented as \((2)\) and \((3)\)

\[
\overline{u_n} = \sum_{k=1}^{n} \alpha_k \rho_k \overline{u_k}
\]  

\text{(2)}

\[
\rho_n = \sum_{k=1}^{n} \alpha_k \rho_k
\]  

\text{(3)}

\(\alpha_k\) is the volume fraction of phase \(k\).

**II. Momentum equation**

The equation general form is as \((4)\)

\[
\frac{\partial}{\partial t}(\rho_n \overline{u_n}) + \nabla (\rho_n \overline{u_n} \overline{u_n}) = -\nabla p + \nabla \left[ \mu_n (\nabla \overline{u_n} + \nabla \overline{u_n}^T) \right] + \rho_n \overline{g} + \overline{F}
\]  

\text{(4)}

Where \(n\) is the number of phases

\(\overline{F}\) is a body force, \(\mu_n\) is the viscosity of the mixture represented as \((5)\), and \(\overline{u_{\alpha,\beta}}\) is the drift velocity for secondary phase \(k\) represented as \((6)\): \[
\mu_n = \sum_{k=1}^{n} \alpha_k \mu_k
\]  

\text{(5)}

\[
\overline{u_{\alpha,\beta}} = \overline{u_k} - \overline{u_n}
\]  

\text{(6)}

**III. Energy equation**

The equation general form is as \((7)\)

\[
\frac{\partial}{\partial t} \sum_{k=1}^{n} \alpha_k (\rho_k \overline{E_k}) + \nabla \sum_{k=1}^{n} \alpha_k \overline{u_k} (\rho_k \overline{E_k} + p) = \nabla (k_{\text{eff}} \nabla T) + S_k
\]  

\text{(7)}

Where \(S_k\) includes any other volumetric heat sources, \(k_{\text{eff}}\) is the effective conductivity, and \(E_k\) represented as \((8)\) for compressible phase or equal to \(h_k\) for incompressible phase.

\[
E_k = h_k - \frac{p}{\rho_k} + \frac{u_k^2}{2}
\]  

\text{(8)}

**IV. Turbulence model**

The turbulent model used for this computational study is k-epsilon standard mixture model. The equations general form for this model is as \((9a, b)\).
3. RESULTS VALIDATION

The heat transfer coefficient of the simulated model was validated using the two phase heat transfer correlations that were developed by Boyko L. D. and Kruzhihin G. N. (1967), Serizawa A. and Michiyoshi I. (1975), Shah M. M. (1981), and Kim D. and Ghajar A. J. (2002). The correlations formulas are as follows.


Developed a correlation to calculate the heat transfer coefficient for two phase in horizontal tube. They used the correlation to calculate the heat transfer coefficient through the condensation of steam for horizontal tube, they validated their correlation using experimental results.

\[ h_{TP} = h_l \left(1 + \frac{\rho_f}{\rho_g} - 1 \right)^{0.5} \]  \hspace{1cm} \text{(10)}

Where the liquid heat transfer coefficient evaluated as (11):

\[ h_l = 0.02 Re_f^{0.8} Pr_f^{0.4} \left( \frac{k_f}{D} \right) \]  \hspace{1cm} \text{(11)}

II. Serizawa A., Kataoka I., and Michiyoshi I. (1975)

Developed an empirical correlation to calculate the diffusivity ratio of the two phase (air - water) heat transfer coefficient to the single phase (water) heat transfer coefficient. The correlation, eq. (12), was used in this paper to calculate the two phase heat transfer coefficient. The single phase heat transfer coefficient are evaluated from Sieder E. N. and G. E. Tate (1936), eq. (13).

\[ \frac{h_{TP}}{h_l} = 1 + 462 X_{TT}^{-1.27} \]  \hspace{1cm} \text{(12)}

\[ Nu_t = 0.027 Re_t^{0.8} Pr_t^{0.33} \left( \frac{\mu_l}{\mu_g} \right)^{0.14} \]  \hspace{1cm} \text{(13)}

Where \( X_{TT} \) is the Martinelli parameter, and \( x \) is the flow quality, evaluated as (14, and 15), respectively.

\[ X_{TT} = \left(1 - \frac{x}{\rho_l} \right) \frac{\rho_f}{\rho_l} \left( \frac{\mu_l}{\mu_g} \right) \]  \hspace{1cm} \text{(14)}

\[ x = \frac{m_g}{m_g + m_v} \]  \hspace{1cm} \text{(15)}


Developed a correlation for horizontal and vertical ducts to calculate the two phase (water - air) heat transfer coefficient.

\[ h_{TP} = \left(1 + \frac{u_g}{u_l} \right)^{1/4} \]  \hspace{1cm} \text{(16)}

Where \( h_l \) is evaluated as (17).

\[ Nu_t = 0.023 Re_t^{0.8} Pr_t^{0.4} \left( \frac{\mu_l}{\mu_w} \right)^{0.14} \]  \hspace{1cm} \text{(17)}


Developed a heat transfer correlation for two phase (air - water) flow, the correlation are developed based on vertical pipes and different patterns experiments data. They modified the correlation to calculate the two phase heat transfer coefficient for horizontal pipes with good accuracy, eq. (18). Liquid phase heat transfer coefficient was evaluated using Dittus and Boelter (1930) heat transfer correlation (19).

\[ Nu_t = 0.0243 Re_t^{0.8} Pr_t^{0.4} \]  \hspace{1cm} \text{(18)}

\[ \alpha = \left[1 + \left( \frac{u_g}{u_l} \right) \left( \frac{1 - x}{x} \right) \left( \frac{\rho_l}{\rho_g} \right) \right]^{-1} \]  \hspace{1cm} \text{(20)}

The deviation percentage between the results is (7.04 %, 6.5 %, 2.71 %, and 18.85 %), respectively, as shown in figure (4). This correlation was compared with smooth duct since it was correlated based on smooth ducts and pipes experiments data.

Fig. 4 Comparison between the heat transfer coefficient of the current work and the correlation developed by Boyko L. D. and Kruzhihin G. N. (1967), Serizawa A. I. and Michiyoshi I. (1975), Shah M. M. (1981), and Kim D. and Ghajar A. J. (2002). At 0.15 m/s air velocity and different water velocities.
4. RESULTS and DISCUSSIONS

Two phase (water-air) flow through rectangular duct that roughed with different shapes ribs (rectangular, trapezoidal, triangle) was investigated using Ansys Fluent 15.0. three values of water and air velocities was studies. Figure (5) shows the local heat transfer coefficient for the duct for smooth and ribbed ducts, for several values of air and water velocities, the trend of the heat transfer coefficient is the same. In the smooth duct the values of the heat transfer coefficient is the same, as for the ribbed duct the value of the heat transfer coefficient are increased also a complex shape are appear, an amplitude are appear periodically. Figure (6) shows the local heat transfer coefficient for rectangular ribbed duct and smooth duct, this figure shows that the amplitude appear at a certain location which is the where the ribs are located. At ribs and the leading edge of the ribs the velocity is increased which increase the heat transfer coefficient, at the trailing edge the velocity are lower which give low value of the heat transfer coefficient. Figure (7) shows the average heat transfer coefficient for the three shapes of ribs with respect to the water velocity and at different values of the air velocity, as it seems the heat transfer coefficient increase as the value of water velocity increase. The same effect are appear as the value of air velocity increase but with less percentage increase as shown in figure (8). Increasing the velocity will increase the turbulence produced in the duct and the flow mixing will increase as well due to the presence of ribs inside the duct which conversely will increase the heat transfer coefficient. Figure (9) shows the Reynolds number effect on the average value of the heat transfer for smooth and ribbed ducts, as the Reynolds number increase the heat transfer increase for both smooth and ribbed ducts but the percentage increase are not the same, ribbed ducts have more heat transfer areas which mean more heat to be translated in to the duct. Heat transfer coefficient for rectangular ribbed duct increased by (73.97 %), as for the trapezoidal ribbed duct increased by (99.14 %), where the triangle ribbed duct increased by (135.65 %). Figure (10, 11, 12) shows the distribution of water and air inside the ducts for the three different shape ribs. The trailing edge of the ribs are place where eddy are formed and recirculation appear. As the velocity of water and air increased the circulation of flow in the duct increase. Figure (13) shows close view for the flow distribution across the rib, the flow at the leading edge of the rib are almost settle whereas at the rib the flow are separated and reattached after the trailing edge. At the trailing edge of the rib the eddy are formed and flow circulation appear. The area for the leading edge and the trailing edge behavior are at its biggest value for the rectangular ribs and at its smallest value for the triangle ribs. Figure (14) shows the temperature distribution for the three ribbed ducts, this figure shows the temperature are at its higher value at the trailing edge of the ribs and for the three ribs shapes.

Fig. 5 Effect of ribs on the local heat transfer coefficient at different values of air and water velocities
Fig. 6 Local heat transfer for smooth and rectangular ribbed ducts

(a) Rectangular ribbed duct

(b) Trapezoidal ribbed duct

(c) Triangle ribbed duct

Fig. 7 Effect of water velocity on the average heat transfer coefficient at different air velocities
Fig. 8 Effect of air velocity on the average heat transfer coefficient at different water velocities

Fig. 9 Effect of Reynolds number on the average heat transfer coefficient for smooth and ribbed duct
Fig. 10  Rectangular ribbed duct (a) 0.4 m/s water velocity and 0.18 m/s air velocity  (b) 0.8 m/s water velocity and 0.18 m/s air velocity

Fig. 11  Trapezoidal ribbed duct at (a) 0.4 m/s water velocity and 0.18 m/s air velocity  (b) 0.8 m/s water velocity and 0.18 m/s air velocity

Fig. 12  Triangle ribbed duct at (a) 0.4 m/s water velocity and 0.18 m/s air velocity  (b) 0.8 m/s water velocity and 0.18 m/s air velocity
Fig. 13 Flow distribution of ribbed duct at 0.6 m/s water velocity and 0.18 m/s air velocity

Fig. 14 Temperature distribution of ribbed duct at 0.6 m/s water velocity and 0.18 m/s air velocity

CONCLUSIONS
In this paper the two phase heat transfer coefficient for ribbed and smooth ducts was investigated using Ansys Fluent 15.0 computational fluid dynamics. The coefficient of the ribbed ducts was compared with the smooth duct and found to be increased by 73.97 % for rectangular ribbed duct, 99.14 % for trapezoidal ribbed duct, and 135.65 % for triangle ribbed duct.
duct. It also found that the heat transfer coefficient increase as the velocity of the flow increase. The distribution of the water and air in the duct was shown as well as the temperature distribution, eddy was shown to be formed at the trailing edge of the ribs and the temperature found to be at its higher value at the trailing edge of the ribs and for the three types of ribs.

NOMENCLATURE

μ: Dynamic viscosity (kg/m.s)
b: Rib pitch distance (m)
cp: Specific heat (J/kg.K)
D: Diameter (m)
e: Rib height (m)
F: Force (N)
f: Friction
g: Gravity (m2/s2)
h: Heat transfer coefficient (w/m2·K)
k: Thermal conductivity (w/m.K)
Nu: Nusselt number (h D/k)
Pr: Prandl number (µ cp/k)
Re: Reynolds number (ρ u D/µ)
T: Temperature (K)
u: Velocity (m/s)
w: Rib base width (m)
x: Flow quality
X: Distance on the x axis
Xr: Martinelli parameter
α: Volume fraction
β: Turbulent dissipation rate (m3/s2)
ρ: Density (kg/m3)
σ: Surface tension (kg/m)

Subscript
a: Air
B: Bulk
G: Gas
k: Phase
L: Liquid
m: Mixture
TP: Two phase
w: Wall, Water

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Stepper Motor Motion Control Through Serial Communication Using FPGA-Based Microcomputer Architecture and Example of Application

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Abstract—In this study, RS232 asynchronous serial communication protocol was implemented on BZK.SAU microcomputer architecture. Thus, the deficiency of the BZK.SAU microcomputer architecture, which was designed for educational purposes, regarding the peripheral units, was resolved through the protocol created, and the experience which was essential for other serial communication protocols was gained. The aforementioned protocol was coded with the hardware description language (VHDL), synthesized on FPGA board, and proper functioning was verified through PC and ModelSim simulation program. In the second part of the study concerned, the mechanism was provided with the ability to perform the return process in the desired direction and angle using the FPGA-based keyboard without computer through Pan/Tilt mechanism formed on stepper motors with the software created with BZK.SAU Assm language which is the language of BZK.SAU microcomputer architecture. In this way, it was observed that the serial data transmitted between two FPGAs and the Pan/Tilt Mechanism connected to FPGA formed a basis for the embedded systems and moving associative mechanisms.

Keywords— BZK.SAU, FPGA, RS232, Stepper Motor

I. INTRODUCTION

FPGAs are programmable integrated circuits which allow designers to perform hardware functions such as a microprocessor, special hardware, memory structure, and external memory controller on a single integrated circuit. FPGAs are preferred in terms of cost and productivity, for they allow each function of every single element to be located on a single circuit board. Furthermore, FPGAs are more practical compared to ASIC in terms of developing applications on the circuit and re-programmability [2].

FPGAs are reprogrammable semiconductor devices containing multiple connections with the matrix structure. Because of their re-programmable structure and ability to function fast and collaterally, FPGAs are ideal integrated circuits for many different markets. They are used in many areas such as biomedical, air-defense, ASIC prototype design, automotive, consumer electronics, high-performance computing, and data storage, industrial applications, video-image processing, and wired-wireless communication. While FPGAs were preferred due to the low speed and capacity in the past, now they have become preferable for their operating speeds that can reach up to 500 MHz [2]. The FPGA integrated circuit located on Altera DE-2 70 board was used in the study concerned [1].

Quartus II is software developed by Altera to program the reprogrammable logical devices. Quartus II allows the analysis and synthesis of the designs in HDL language. It is highly successful software in the compilation of the designs within all these processes, making time-performance analysis, calculation of RTL diagrams, and simulation of different designs [3]. Quartus II software was successfully used in this study to program the FPGA integrated circuit [1].

Modelsim simulation software created by Mentor Graphics is an important tool to simulate designs created by hardware-based languages such as VHDL, Verilog, and SystemC [4]. The designs on which the studies were performed were simulated in Modelsim program [1].

Digital designs in this study were developed in VHDL. VHDL (Very High Description Language) is a special language created to describe digital electronic systems. It is particularly used to program logic-based integrated circuits such as FPGAs. VHDL was created by the USA [5]. One of the biggest advantages of the VHDL language is that it enables to make digital designs which work sequentially and collaboratively in a fast and flexible way [6].

Stepper motors are electrical motors converting the electrical signals which are applied sequentially into sequential movements. Controlling stepper motors of embedded systems such as FPGAs, in particular, has been taking place in the studies in recent years [7-8-9]. In the study performed, 64-step reduction unipolar stepper motors were used [1].

Among the studies carried on the realization of RS232 standard, which is a serial communication protocol, on FPGA, the Uart Module design and its integration into the microprocessor are at the forefront [10-11-12]. Therefore, to develop the concerned protocol was one of our fundamental aims.
In the doctoral thesis study on FPGA-based microcomputer named BZK.SAU, the RS232 serial communication protocol which is one of the protocols that are essential for data communication with the outer world was created with VHDL; and the control design, the software of which was created in BZK.SAU with BZK.SAU.ASSM language, was realized in the desired serial data transfer speed without loss [1].

Thus, each data compiled within BZK.SAU and sent to output serial recorders communicate with other FPGAs through RS232 communication protocol, and the data transfer takes places at the desired serial data transfer speed without loss and seamlessly [1].

The subheadings are as follows:

A. BZK.SAU Architecture, Serial Communication and the Position Control

II. METHOD AND MATERIAL

In this study, the FPGA shown as FPGA-1 in which BZK.SAU microcomputer architecture was embedded and the FPGA shown as FPGA-2 on which RS232 serial communication protocol was loaded were connected to each other with a single cable structure or with the cable structure manufactured as the standard for 9-pin headers. Thus, each data compiled within BZK.SAU and sent to output recorders communicate with other FPGAs through RS232 serial communication protocol, and the data transfer takes places at the desired serial data transfer speed without loss and seamlessly [1].

The designed RS232 asynchronous serial communication protocol was created with VHDL language into two parts, which were serial-data-sending part and serial-data-retrieval part, and fully integrated into the BZK.SAU microcomputer architecture.

In the second part of the study concerned, the control algorithm coding was done which had been designed within the BZK.SAU microcomputer architecture with BZK.SAU.ASSM language and the angular control on the stepper motors moving within a two-axis Pan-Tilt mechanism was achieved. The data input for the biaxial control within the concerned control system was realized through directional data received from the keyboard structure of BZK.SAU. Thus, in addition to the rotation of the open-loop control structure at the desired angle, the angular rotation characteristics of the stepper motors which they had for each step were realized thanks to this system. The biaxial control structure was named as Stepper Motor-1 and Stepper Motor-2 in the schematic illustration [1].

The directional and angular control of the stepper motors was realized through the stepper motor drive circuit connected to the GPIO-1 and GPIO-2 pinouts located on FPGA-2 [1].

The 16-bit data bus and address bus were used in BZK.SAU microcomputer architecture. The related study addressed 16-bit data bus 64Kbyte memory in BZK.SAU microcomputer architecture. In the BZK.SAU architecture designed, a VGA-type monitor with 640x480 pixels resolution was used. The monitor hardware was a hardware which worked only in text and single color (red) mode, and each character on the monitor screen was represented with 8x16 pixels. The related study works on DE2-70 FPGA board with the keyboard structure and the monitor [1].

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B. Serial Data Delivery Algorithm and Its Simulation

RS232 serial communication protocol was coded into two parts with VHDL language in the thesis study performed. These two parts were designed as serial data-sending part and data-retrieval part.

Moreover, the digital structure used as a frequency divider in both designs was created in VHDL language as well. The algorithm and simulation in Modelsim of the related design are shown in Figure-2 and Figure-3. The designed communication algorithm was formed according to the RS232 asynchronous serial communication protocol, simulated and tried on the FPGA circuit board. Thus, the serial data stream between the real-time-running-system was realized. The experiment to test whether the circuit sending serial data worked correctly and at the desired speed was performed with the software called “RealTerm Serial Capture Program” [1].

C. Serial Data-Retrieval Algorithm and Its Simulation

The basic function that the serial data retrieval algorithm fulfills is to retrieve the serial data sent at the baud rate of speed and convert it into the parallel data. In order to determine whether the data coming from the 8-bit input register of BZK.SAU.FPGA are meaningful data, first of all, the fall time of the data line from logic 1 to logic 0 is checked in accordance with the RS232 protocol; if the received data at the first fall time is logic 0 data, it is recorded in the first vector or index which is called data buffer (0). That the data buffer (0) is at logic 0 level activates a signal called “Load”, and as a result of this, the following data are received into the same index. Because of the fact that data buffer (9) bit at logic 1 is the stopping bit within the framework of the RS232 protocol, it enables the transmission of the data buffer (1-8) data bits to the output in the following algorithmic step. Each step taking place in a particular design depends on a particular clock structure, as in all digital designs. At each rising edge of the clock, the next state within the code structure is passed. Thus, all states coded within the algorithm follow each other [1].

D. Pan/Tilt Mechanism and Stepper Motor Control Software

In this study, a code structure was created which enables the rotation in the desired direction and/or at the desired angle with BZK.SAU.Assm language within BZK.SAU microcomputer architecture. The algorithm enabling the mentioned movement system is shown in Figure-8.
The control software created with BZK.SAU.Assm language in the study concerned has the ability to move the Pan/Tilt Mechanism angularly in the desired directions. 9 of 59 code structures within BZK.SAU.Assm were used, and the movement algorithm is shown in Figure-8. Some of these commands are battery and memory commands, and some are input and output commands [1].

III. CONCLUSION AND DISCUSSION

The asynchronous RS232 serial communication circuit the design of which was made on BZK.SAU microcomputer architecture which was designed for educational purposes was the main purpose of the study performed. In this way, the elimination of the shortcomings of the peripheral units on BZK.SAU microcomputer architecture, which had already been brought into the literature, which are necessary to data-communication with the outer-world, ensures the originality of this thesis study. In addition, it is considered that the obtained knowledge and experience will be a base study for creating computer-based and device-based serial communication protocols such as USB, I²C, Ethernet, and for the control systems with angular position control embedded system base for biaxial PAN/TILT mechanisms created on stepper motors with software structure.

REFERENCES

A Comparisonal Study on Unbalance Failure in the Perspective of Vibration and Electrical Consumption Analysis

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Abstract—In this research, condition of resonance effect which is a common problem for mechanical constructions has been studied in perspective of unbalance failure of a bearing. A test setup designed respect to case practices; constructed and located in laboratory conditions. A bearing in the electrical motor, that is one of the elements in the test setup, has been selected for gathering data in vibration and electrical consumption during the test. The purpose of the research is testing condition of unbalance failure and resonance for studying comparison in various predictive maintenance approaches. Test has been implemented under the electricity frequency of 40.5 Hz that induced the electrical motor for determining rotational speed. According to the analysis results, inspecting of unbalance failure and resonance problem has been detected more clearly by vibration analysis.

Keywords— electrical consumption, unbalance, resonance, vibration, fourier

I. INTRODUCTION

Energy efficiency maintenance techniques are in the stage of rapid development due to competitive markets and globalization. Mainly, enterprises of developing countries are in demand of high technology implementations for mechanical maintenance in order to leave classic techniques such as breakdown maintenance, periodic maintenance etc. Vibration based maintenance is one of the techniques which is used commonly in industries that prefer predictive maintenance. As long as since the stage of failure initiation, machines consume more electricity respect to the stress in machine elements. By studying data belongs to electricity consumption regarding voltage and current, it brings a newer approach on detecting failure types and severity respect to the signal processing. Vibration analysis is based on the signals those gathered as targeting on bearing, but electrical data is received over electricity usage of the motor. Interpretation of vibration analysis has algorithm based on rotation frequencies caused by the rotational speed; and electrical consumption analysis is based on signals of electrical frequency that is in use.

Nowadays, reliability concept is used more commonly in the development of manufacturing industries. Design of products with high reliability is needed, but against to deterioration in the life cycle of the product, maintenance is a method in maintenance [1]. Prognostic and diagnostic terms are known from medical areas and they are used for the machine health as well. Currently, a variety of sensors and some other equipments are used successfully in receiving signals for studying the root causes of the mechanical failures [2]. In order to cope with the competitive markets, assistance of the high technology such as sensor technology is crucial for the enterprises. On the other hand, investment on high technology does mean always positive results. Appropriate sensors for the target aim, qualified personnel and right interpretation of the data are other important factors for successful actions [3]. One of the failure detection methods for electrical motors is collecting signals of voltage and current and study them [4].

Electrically forced machines are very common in production areas. Breakdown of these machines brings many losses to the enterprises such as time loss, quality loss, capita loss. In order to prevent these kind of losses, maintenance need was born [5].

Machines have characteristic properties on failure types respect to the vibration signals oscillated. Machine failures are mostly studied under assistance of vibrational analysis [6]. Spectrum analysis is a method for identifying the frequencies of a signal. Fourier transform deals with signals that are studied respect to the time parameter as sine and cosines; and to the frequency parameter that is the same signal which is categorized according the frequencies [7].

II. MATERIALS AND METHODS

Test setup constructed through consisting of double inlet fan, AC induction motor, five feet of flexible coupling and frequency inverter. The test setup is constructed over a steel sheet and a steel tripod. The test setup is put up on a double-decker rubber sheet that is mounted between the test system and the tripod; also, a vacuum rubber below the feet of the tripod takes place over the floor. This system with a data acquisition card and an induction motor is communicated with monitoring system through a computer. Testing system in Figure 1 presents a real appearance from testing setup.
Frequencies took place in the test (T) and measured (M) are given in Table 1. Theoretical frequencies means the value set on the digital frequency changer; according to data studied during the application, actual frequency ranging had some losses. 1x is named as a frequency that is known as fundamental frequency; 2x, 3x and the upper orders are harmonics of the fundamental frequency. In Table 1, the frequency is presented with the symbol of f for frequency converter and harmonic order is shown with symbol of h.

<table>
<thead>
<tr>
<th>(f)</th>
<th>T</th>
<th>M</th>
<th>T</th>
<th>M</th>
<th>T</th>
<th>M</th>
<th>T</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.5</td>
<td>40.5</td>
<td>39.06</td>
<td>81</td>
<td>78.12</td>
<td>121.5</td>
<td>117.18</td>
<td>162</td>
<td>156.24</td>
</tr>
</tbody>
</table>

Measurements are received during the tests at electrical frequency of 40.5 Hz and rotational level was measured as 2350 min⁻¹. Frequencies of faults and harmonics are studied for calculating the bearing and fan-induced vibrations of the testing setup.

Bearing relevant equations with the basic failure frequency calculations and respect to measurements are given in Table 2.

<table>
<thead>
<tr>
<th>(f)</th>
<th>0ₗ (Hz)</th>
<th>0ᵦᵣᵦₑ (Hz)</th>
<th>0ᵦᵟₛ (Hz)</th>
<th>0ᵦᵦₑ (Hz)</th>
<th>0ᵦᵦₑ (Hz)</th>
<th>0ᵦᵦₑ (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.5</td>
<td>39.06</td>
<td>390.6</td>
<td>14.84</td>
<td>118.74</td>
<td>193.76</td>
<td>76.69</td>
</tr>
</tbody>
</table>

ωᵦᵢᵢᵢ: Outer ring passing frequency (Hz), ωᵦᵢᵢᵢ: Inner ring passing frequency (Hz), ωᵦₛ: Ball spin frequency (Hz), ωᵦ: Cage frequency (Hz), ωₗ: Shaft frequency (Hz), ωᵦᵦₑ: Fan blade passing frequency (Hz)

Tested bearing has been presented in Figure 2.
through an electronic device connected to electrical circuit of the motor and analyzed with its software.

**A. Vibration Analysis**

Under the effect of unbalance failure in axial direction, respect to the findings at frequency of 40.5 Hz; harmonic 1x is detected with the highest amplitude. 1x is the characteristic feature of unbalance failure. Similarly with the radial direction, signal at harmonic 1x has the highest amplitude with 0.785 m/s² but less than the radial direction which is 1.19 m/s². In comparison with highest five amplitude signals in axial and radial direction, four signals are detected at same frequencies as 39.06 Hz, 120.8 Hz, 78.13 Hz and 947.3 Hz. In the axial direction, natural frequency signal at 1027.8 Hz is excited by the bearing signal at 69xωc has been detected which does not exist in radial direction dominant signals.

![Figure 4. Spectrum in axial way](image)

Respect to the Figure 4 and Table 3, unbalance condition increased the vibration magnitude of signals at the element passing zone.

**B. Electrical Consumption Analysis**

Standart deviations in measurements are evaluated in perspective of electrical consumption, data is given in PSD analysis and trend analysis. Respect to PSD analysis in Figure 6, peaks can be seen at the orders of 40.5 Hz. Highest three amplitudes are on 40.5 Hz, 81 Hz and 121.5 Hz. According to the methodological approach of device software, band at the main frequency represents the condition of the rotor, band at the second order represents the unbalance failure and band at the third order represents the any other failure. The PSD analysis takes attention to rotor and unbalance failure.
According to the data gathered and processed; PSD analysis gives more detailed results in comparison with trend analysis.

Figure 6. PSD values

According to evaluation of trend analysis in Figure 7; in comparison with the reference level, unbalance indicator has not detected any change in the condition of unbalance effect respect to the load on wings.

Figure 7. Trending values

IV. RESULTS AND CONCLUSIONS

In this test study, resonance effects of a test construction have been studied under the unbalance condition of a bearing in an electrical motor with the excitation of electricity frequency at 40.5 Hz. Through predictive maintenance perspective; techniques of vibration and electrical consumption analysis are studied in order to identify the condition of a tested bearing under unbalance failure.

According to test results of vibration analysis; bearing failure frequencies and resonance frequencies are identified in spectrum domain under the effect of unbalance failure.

Electrical consumption analysis is successful on detection of unbalance failure in PSD analysis but not sensed in trend analysis. It is assumed that analysis programme of the measuring device is not designed for identifying resonance effect. But resonance effect may be studied in band of rotor or band of other; not exist sufficient data about it.

In comparison of vibration and electrical consumption analysis results; vibration analysis has been evaluated as more informative and superior tool for detecting the resonance features of the tested system in the condition of unbalance failure.

REFERENCES

Development of a 3D Laser Scanning System for Localization and Mapping in Robotic Applications

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Abstract—In the recent decade, one of the most important topics in researches and developments is the studies performed in robotic and mechatronics applications. Especially, the mass production systems, automobile industries and military-defense products are continuously enhanced. They strictly follow and adapt the new methodologies, approaches, systems and tools created in robotic and mechatronics research world. Their common objective is to develop better autonomous / automation systems. While such autonomous systems are designed, some tools used for scanning and recognizing the working environment are required. Considering the efficiency, repeatability, accuracy and environmental conditions, laser scanning systems are generally preferred to meet these expectations. They are used for mapping the surrounding of the working area. If the system is mobile, they are also used for localization. In this study, a 3D laser scanning system based on a 2D laser scanning rangefinder is developed. The system consists of a rotating unit on which a 2D laser scanner is placed. Rotation is provided using a stepper motor. The rotation control of this unit is achieved using a motion controller. A high resolution encoder and encoder interface card are also plugged into the system to get the direct rotation angle information. By this way, the required feedback is supplied to the control structure developed. The use of high resolution encoder provides also getting rotational velocity with high accuracy. The position and velocity control of the rotating parts of the system are controlled using an ATmega based microprocessor. Not only the control issues of the rotating parts, but also data flow and process of the 2D laser scanner is performed in real-time. The decoding process of the laser sensor is done using an algorithm created in C++. In order to create the 3D map of the surrounding, the data coming from the laser scanner and the rotation angle information obtained from high resolution encoder are integrated under a mathematical model built in Matlab/Simulink. Many experiments are conducted and successful results are obtained.

Keywords—Localization, mapping, robotics, laser scanner.

I. INTRODUCTION

In the robotic and mechatronics research areas, developments have been constantly continued for the last decades. New ideas, modeling structures, control algorithms, tools, systems and machines have been proposed and taken place in the robotic and mechatronics world. In any robotic application, one of the important issues is the recognition of the working environment. In other words, the surrounding should be perceived and this requires some tools behaving like eyes. Cameras are commonly used for this objective. The negative side of using cameras is that they cannot be adapted to all robotic applications. For instance, the applications requiring high resolutions and accuracy may not be appropriate for adapting camera systems for recognition purpose. The use of cameras needs also high-rate computational efforts that can be performed by using high-performance computing systems. Furthermore, the light quality (in the case camera is used as a recognition tool) should be perfect for obtaining high accuracy. The solution adapted in such cases is to use laser scanning range finders. According to the working principles of the laser scanners, they provide 2 dimensional data for their surroundings. In the obstacle detection / avoidance applications, getting the information about the location of an obstacle is enough to plan the desired trajectory. In such a case, a 2D laser scanning range finder can effectively be used for achieving the task. If the shape of the obstacle in 3D space (rather than its location) is important, a 3D laser scanner would be used.

There are 3D laser scanners available in the market. Different models ranging from low to high resolutions can be obtained. In addition to low accuracy models, high accuracy and high quality models are offered to the customers. The disadvantage of these 3D laser scanning range finders available currently in the market is the cost of them. They cannot be affordable for the small-scale projects, student works, workshop applications and prototype developments.

In this study, a 2D laser scanning rangefinder based 3D laser scanning system is developed. The system consists of a mechanical frame and a rotational unit. The rotational unit is constructed by using a flat platform, rotational shaft, bearings and couplings. It is actuated using a stepper motor. A L298D motion controller is adapted to achieve the controlling purpose of the stepper motor. In order to increase the rotational accuracy of the laser scanning system, a high resolution encoder is coupled to the system. It is connected to the system using a gearbox mechanism. The motion control unit used for position and velocity controls of the stepper motor is commanded via using an ATmega based microcontroller. The rotation information coming from the high resolution encoder is decoded using an encoder input card manufactured by Quanser. A laser scanning range finder, Hokuyo URG-04LX, is located on the rotating unit of the system. Its data is processed using an algorithm created in C++. All the subsystems including data processing, data fusion and command generation for the controller are merged in
Matlab/Simulink environment. Using the Real-time workshop toolbox of Simulink provides the real-time control opportunity of the system. The 2D laser scanner data is easily combined with the rotation angle information in this computation environment.

The outline of this paper is constructed as follows: the next section is about the related studies. The problem statement is given in Section 3. The design and construction processes are presented in Section 4. Experimental studies and their details are also demonstrated in this section. The analysis and conclusion of the study is given in the last section of the paper.

II. RELATED STUDIES

There are number of studies related to developing a 3D laser scanning system in the literature. In this section, some of them are reviewed to see the current technology in the 3D laser scanning systems and make a comparison between the literature and the study proposed here.

A 3D laser scanner was developed for measuring uniform and dense shapes in dynamic environment. The 3D laser system was constructed based on a 2D laser scanning range finder that was mounted on a pan tilt base. The rotation of the pan tilt base gave the 3D shape measurement opportunity. The proposed system was supported by using a point clouds algorithm [1]. A low-cost and instant 3D laser scanning system was proposed. The system was designed for creating 3D models. It was aimed that the data obtained from the proposed system could be used for 3D printing tasks. In addition to mechanical parts of the overall system, computational and communicational parts were also designed. The performance of the system was presented via the number of experimental results [2]. A low-cost active 3D triangulation laser scanning system for indoor navigation of mobile robots was designed. A camera and laser scanner were integrated in a system and located on the movable part of a robot. The movable part was actuated using a servo motor. By this way 3D laser scanner based on a 2D laser sensors was created [3]. A cost effective and hand held 3D laser scanning system was developed. The system was designed for acquiring the optical 3D laser scan data. An automatic registration algorithm was also built for 3D shape modeling [4]. A new methodology to analyze coarse tree root using a 3D laser scanning system was developed. The study focused on obtaining solutions for the problems of constructing detailed 3D data acquisition and modeling its complex structure [5]. A high precision 3D laser measurement system was developed. The system was designed using multiple mobile robot cooperation. The robots, two of them were child and one of them was a parent, were suited with number of sensors and laser scanners. An algorithm was developed to achieve the data flow between the robots and coordination [6]. A high quality 3D laser scanning system for general vehicle usage was proposed. The system was constructed based on a 2D laser scanning range finder and point clouds algorithm. The methodology introduced was tested for an outdoor 3D navigation task [7]. An automatic planning of laser measurements for large scale environment was introduced. The system used multiple robots. One of the robots was suited with a 3D laser scanning system and the others were aimed for marking the targets. The algorithm proposed was able to process the large scale of 3D data to construct the working environment of the mobile robots [8]. A low-cost laser scanner with 360° field of view for mobile robotic applications was developed. The system consists of a 2D laser scanner and a rotating head part. The proposed system also provided an intrinsic calibration method for the device built. The integration of the scanning system with a mobile robot was also presented [9]. A laser scanning sensor system for outdoor service robots was developed. The study consists of design, manufacturing, implementation and experiments. The laser system was constructed based on a 2D laser scanner and a rotating unit which was actuated using an actuator. It consisted also a CCD camera installed to the system in order for increasing the measurement accuracy of the overall system. The sensorial subsystems and the actuator were integrated using an algorithm developed [10].

What distinguishes this study from the ones presented above is that a low-cost and high accuracy 3D laser scanning system is developed. The construction of the system needs very basic steps and it can guide the researchers for the further enhancements on laser scanning systems. A new methodology consisting of the data fusion, data mining and actuator control issues is also presented in this paper.

III. PROBLEM STATEMENT

The recognition of the obstacles is one of the important issues in robotic and mechatronics applications. In addition to recognizing the working environment, creating a safe space is the key factor for achieving a robotic task. The automation applications can also require such obligations for performing the desired objective. In an autonomous vehicle application, the obstacles should be detected so that the desired trajectory can be tracked. This task is depicted with a scenario in Figure 1-a. In this scenario, the four-wheeled autonomous vehicle is aimed to track a reference path indicated by blue-dashed-line. It moves with a desired forward velocity specified by $V_c$. A laser scanning range finder is mounted to the front mid-center of the vehicle so that the vehicle can be able to detect any obstacle, person, vehicle, etc. inside its desired path. The coverage of the scan of the laser scanner is specified via red-colored-circle. Three obstacles (shown by black-colored-solid-boxes) are located in front of the vehicle. The vehicle should detect them so that it can follow the desired path without having an accident. The expected detections of the obstacles by using the laser scanner are given in Figure 1-b. In this figure, the obstacles detected and the detection coverage between the laser scanner and the obstacles are indicated. The detection coverage is shown by red-colored-areas (Area-i, $i=1,2,3$). By this way, the position and orientation of the obstacles can be specified and the desired trajectory can be safely and effectively generated according to this information.
In this study, development of a 2D laser scanning range finder based 3D laser scanning system is focused. As shown in Figure 1-a, a 2D laser scanner scans its surrounding in 2D, that means a height information of an object cannot be obtained. The environment can be scanned by only slices. In this study, the number of slices is intended to increase from 0° to 180° (Figure 2-a) by using a rotating mechanism. The resultant scan coverage is expected as shown in Figure 2-b. A 3D coverage (a half of a ball) can be created using the system proposed in this study. The rotating mechanism is able to give a point clouds which can be used to recognize the objects with their complete shapes.

In this study, a laser scanner range finder (Figure 3) is attached to the scanning system developed. The placement of the laser scanner in the 3D scanning system and the CAD view are illustrated in Figure 4. The laser scanner used in this study is Hokuyo URG-04LX. The baudrate speed of it can be set to 19.2, 57.6, 115.2 and 500 Kbps. In this study, the speed is adjusted to 19.2 Kbps. The communication between the main computing unit and the sensor is performed via RS232 serial protocol. The angular resolution of the laser scanner is 0.360° (360° / 1024) and the scanner is able to scan its surroundings from 0° to 240° (Figure 3-b) with 10 Hz. The minimum and maximum measurement distances are 60 mm, 4095 mm, respectively. The angular resolution is about 1 mm.

Matlab-Simulink environment is utilized for achieving the computational and communicational tasks. The real-time workshop toolbox of Simulink is configured to perform the data flow processes and computational efforts.

Encoder input card that is used for counting the number of rotations is shown in Figure 5. It is manufactured by Quanser and able to work with the high resolution quadrature encoders.
The mechanical parts of the system manufactured are illustrated in Figure 6. The stepper motor, which has 1.80 step angle, works with 24 V DC voltage. It is connected to the rotating head with a mechanical combination consisting of a rotating shaft, bearings and couplings. Encoder is coupled to the system via a mounting unit and a gearhead having ratio of $\frac{1}{2}$. Mechanical frame is manufactured from steel. A safety limiter is also added to the system to protect the laser scanner from an undesired accident.

The block diagram of the system constructed is presented in Figure 7. The encoder input card and the laser scanner rangefinder run together inside Simulink. Laser data coming through RS232 serial port is decoded using the S-function feature of Simulink. Stepper motor control is achieved by an algorithm developed in C/C++ environment. It is driven via an ATmega based microcontroller. The encoder data, which is captured by the encoder input card (shown in Figure 5), is processed in Simulink as well.

2D laser scanning range finder data, which forms the 2D point clouds, are shown in Figure 8. In this experiment, the scanning processes introduced above are tested to detect the objects in 2D. The objects detected are indicated by red-colored-filled-circles. Note that the laser scanner is located at the point (0, 0).

The system introduced above is tested to detect the shape of a rectangular box. The laser scanning system is located inside a box and the performance of the algorithm is tested. The point clouds view of the experiment is presented in Figure 9. The results indicate that the dimensions and shape properties of the box can be obtained using the point clouds data.

V. ANALYSIS AND CONCLUSION

In robotic and mechatronics applications, mapping and localization are the important issues. In order to achieve such objectives, easy-to-use and easy-to-adapt recognition systems are needed. Furthermore, they should give accurate and reliable results. In this study, a 3D laser scanning system is developed so as to meet these expectations. The system is constructed based on a 2D laser scanning range finder sensor. A mechanical frame is designed and a rotating head is coupled with it. The rotating head on which the 2D laser scanner is mounted is actuated using a stepper motor. The rotation angle information is acquired via using a high resolution encoder.
The whole system is combined in Matlab/Simulink for real-time use. Many experiments are conducted and successful results are obtained. In the next plan, the laser scanning system will be adapted to a wheeled mobile robot so that the performance of it can be observed in real working environments.

ACKNOWLEDGMENT

The authors would like to thank to the infrastructure project of the Mechanical Engineering Department of Bulent Ecevit University (Zonguldak, Turkey), numbered 2013-77654622-03, for providing the laser scanner rangefinder and the encoder input card used in this research.

REFERENCES

PID Controller Design for Human Elbow Therapy

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Kayseri, Turkey
3 Department of Physical Medicine and Rehabilitation
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Kayseri, Turkey
{ikbal, ahmetkirnap, mkirnap}@erciyes.edu.tr

Abstract—A controller design for mechatronic system which capable of doing passive therapeutic exercises of patients who have upper extremity limitation is presented in this paper. Expectation from controller is it should produce torque values can exactly repeat degree values depended on time which were taken from first therapy exercises of patients. The designed controller tested with real angle values which was taken from during elbow therapy. Simulation results showed that the proposed control system has good performance at tracking the therapy trajectory. Also that control system may be used for mechatronic upper limb therapy system which can be produced.

Keywords—Controller design, limitation at human joints, therapeutic exercises, therapy system.

I. INTRODUCTION

Autonomous rehabilitation machines advantages realized by people day by day. Controllers are most important part of that machines so controller design is the most important topic. Several studies about human motion tracking, rehabilitation machines and controller design for that machines are outlined in this section.

Zhou et al. compared many human motion tracking methods with each other. Their conclusion is inertial sensors is the best method for human motion tracking in terms of ease of use and data accuracy [1-6]. Continuous passive motion device for shoulder is designed by Rasyid et al.. The device can be used for joint motion limitation [7]. Mihelj et al. used ARMin exoskeleton robot at their work and they proposed new patient-cooperative control strategy for upper limb rehabilitation device. They aimed provide support to patient with minimum intervention. In this way patient can use trajectory what he or she wants while reaching the destination point [8]. Birch et al. designed rehabilitation device can be used either continuous passive motion (CPM) or continuous active motion (CAM) for human hand rehabilitation. Device activelyresisting the movement at CAM mode and at CPM mode they used PD control [9]. Saputra et al. used microcontroller to control automatically working CPM device. That device use for knee joint rehabilitation. When patients feel pain, DC motor overloaded so device stops movement [10]. Dong et al. developed intelligent controller and prototype rehabilitation device for human joints [11]. Hassani et al. developed device that perform passive and active motions. That devices main objective is helping health staff [12]. Zhang et al. designed intelligent neural network controller for active rehabilitation device. They used BP neural network for estimation of human knee joint angle change [13]. Prashant et al. designed parallel rehabilitation robot for human ankle movement. They used kinematic analysis and genetic algorithm for optimization [14]. Rehabilitation robot for human ankle, knee and hip joints designed by Wang et al.. They used swarm algorithm for optimization problem [15]. Lee et al. placed artificial mechanism at human knee joint and they gave mathematical model for that artificial mechanism[16]. Chua et al. measured angle change of human hip and knee joints and they designed rehabilitation robot [17]. Yildirim and Eski designed neural network analyzer for human hip and knee joints and they used vibration data of human hip and knee joints [18].

In this paper, we designed controller with data's which are taken by using inertial sensors. This controller is tracking exercise trajectories for elbow joint.

II. DYNAMICS OF HUMAN UPPER LIMBS

There were several different modeling's including human upper limbs in the literature. In this paper, the assumptions were made that human arm consist of three rigid limbs and have three-degree of freedom. Each of the joints was modeled as one-degree of freedom joint.

Relationship between the external forces and displacements generated by external forces could be expressed by linear transfer function which generally called as mechanic impedance or admittance. Basic linear expression of one DOF (single joint) musculoskeletal system in Laplace domain:

\[ \dot{\theta}(s) = \frac{1}{Is^2 + Bs + K} [T_a(s) + T_e(s)] \] (1)

where \( \theta \) is the joint angle, \( I \) is the inertia moment, \( B \) is the joint viscosity, \( K \) is the joint stiffness, \( T_a \) is the torque of muscle and \( T_e \) is the external torque. Here, the visco-elastic joint features depending on joints itself, visco-elastic features of passive component of muscles and visco-elastic features of activated muscles. The muscles visco-elastic features can be divided into intrinsic system and reflexive system. \( B \) and \( K \) at Eq. 1 is include intrinsic system features but not include
reflexive system. The muscles reflexive torque can be modeled as:

\[ T_m(s) = -\frac{\beta_0 s + \beta_1}{\alpha s + 1} e^{-\tau s}(2) \]

where \( \beta_0 \) is the position feedback gain, \( \beta_1 \) is the velocity feedback gain, \( \tau \) is the loop delay and \( \alpha \) is the time constant. While using Eq. 1 for calculation of the human dynamics, if the reflexive torque is too small or muscle activation dynamics can be neglected, the joint dynamic equation will be second-order system [19].

Considering muscles are in fully relaxed condition and muscle activity will be nearly zero during the passive therapy exercises, the muscle reflexive torque \( T_m \) can be neglected because it will be nearly zero. According to this in Eq. 1 angle only depends on external torque and intrinsic system as Milner et al. [20] and Morita et al. [21] used at their work. So dynamic equations for human joints separately modeled as second-order system is given by:

\[ I\ddot{\theta} + b\dot{\theta} + k\theta = T \]

***III. System Modelling***

For designing controller, firstly we need the dynamic model of shoulder, elbow and wrist joint. We use Eq. 3 and Fig. 1 for modeling human joints.

\[ x = \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \end{bmatrix} \]
\[ A = \begin{bmatrix} 0 & 1 & 0 & \ldots \\ -\frac{K_1}{I_1 + I_2 + I_3} & B_1 & 0 & \ldots \\ 0 & 0 & 0 & \ldots \\ 0 & 0 & 0 & \ldots \\ 0 & 0 & 0 & \ldots \\ \ldots & 0 & 0 & 0 \\ \ldots & 0 & 0 & 0 \\ \ldots & 0 & 0 & 0 \\ \ldots & 1 & 0 & 0 \\ \ldots & 0 & \frac{K_2}{I_2 + I_3} & \frac{B_2}{I_2 + I_3} \\ \ldots & 0 & \frac{K_3}{I_3} & \frac{B_3}{I_3} \end{bmatrix} \]
\[ \begin{align*}
\dot{x}(t) &= Ax(t) + Bu(t) \\
y(t) &= Cx(t) + Du(t)
\end{align*} \]

As you seen in the Fig. 1, Eq. 4 expressed for shoulder joint, Eq. 5 for elbow joint and Eq. 6 for wrist joint. State-space model for Eq. 4-6 is:

\[ I_1\ddot{\theta}_1 + B_1\dot{\theta}_1 + K_1\theta_1 = T_1 \]
\[ I_2\ddot{\theta}_2 + B_2\dot{\theta}_2 + K_2\theta_2 = T_2 \]
\[ I_3\ddot{\theta}_3 + B_3\dot{\theta}_3 + K_3\theta_3 = T_3 \]
For shoulder, elbow and wrist, dynamic parameters, which for fully relaxed condition and with minimum muscle activity of human extremities, given in Table I [19, 20, 22-24].

\[
B = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 1 & 0
\end{bmatrix}
\]

\[
C = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 \\
0 & 0 & 1 & 0 & 0
\end{bmatrix}
\]

\[
D = [0]
\]

For shoulder, elbow and wrist, dynamic parameters, which for fully relaxed condition and with minimum muscle activity of human extremities, given in Table I [19, 20, 22-24].

<table>
<thead>
<tr>
<th>I_1 (Hand)</th>
<th>Wrist joint</th>
<th>Elbow joint</th>
<th>Shoulder joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005 kg/m$^2$</td>
<td>0.003 Nms/rad</td>
<td>3 Nm/rad</td>
<td></td>
</tr>
<tr>
<td>I_2 (Forearm)</td>
<td>0.013 kg/m$^2$</td>
<td>0.2 Nms/rad</td>
<td>2 Nm/rad</td>
</tr>
<tr>
<td>I_3 (Upper arm)</td>
<td>0.015 kg/m$^2$</td>
<td>0.3 Nms/rad</td>
<td>10 Nm/rad</td>
</tr>
</tbody>
</table>

IV. EXPERIMENTAL AND SIMULATION RESULTS

At this section, data which are taken from patients has limitation on elbow joint and control techniques developed based on these data results are given. According to taken data from patients elbow joint, PID (Tune) and PID (ZN) control systems are designed. Matlab's PID tuning algorithm and Ziegler-Nichols algorithm are used to adjustment of PID's gain parameters and gain parameter given in Table II Transient state responses of control structures for step input are shown for the elbow joint at Fig. 2. As seen in Table III, the PID (ZN) control structure has given best results on rise time and settling time but overshoot.

![Fig. 2 Control structures response for the elbow joint using unit step input signal](image)

<table>
<thead>
<tr>
<th>Control Structures</th>
<th>Kp</th>
<th>Ki</th>
<th>Kd</th>
<th>Filter coefficient (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID (Tune)</td>
<td>4.14</td>
<td>27.97</td>
<td>0.152</td>
<td>1849.93</td>
</tr>
<tr>
<td>PID (ZN)</td>
<td>12</td>
<td>120</td>
<td>0.3</td>
<td>-</td>
</tr>
</tbody>
</table>

Simulation results for proposed controllers with patient data's has shown at Fig.(3,4). Data's taken from patients who has elbow joint limitation. Patient - 1 is 61 years old male and has limitation at right elbow joint, Patient - 2 is 19 years old and has limitation at right elbow after fracture.

![Fig. 3 Elbow joint angular variations of patient 1 using a) PID (Tune) controller b) PID (ZN) controller](image)
As seen in figures, PID (ZN) control system has minimum steady-state error and giving better results on adapting with the PID (Tune) control systems.

V. CONCLUSIONS

In this paper, control structure designed according to taken data from patients who has limitation elbow joint and different physical specifications. According to experimental and simulation results, the PID (ZN) control system is better than PID (Tune) on adapting and it has minimum steady-state error. Although, PID (ZN) gives better results than PID (Tune), for future work other intelligent control structures will be simulated and compared with PID (Tune) and PID (ZN) control systems.

ACKNOWLEDGMENT

We would like to thank Erciyes University Department of Physical Medicine and Rehabilitation physiotherapists and Erciyes University Scientific Research Projects Coordination Unit (ERU/BAP).

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REFERENCES

Gain Parameter Adjustment Methods Comparison of Controller for Autonomous Rehabilitation Device

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Abstract— PID controller design and comparison between two different gain parameter adjustment method for autonomous physical rehabilitation device is presented in this paper. This device will be capable of doing repeated therapeutic exercises of shoulder joint. That devices main objective is reducing physiotherapist work load. The controllers tested with real angle values. Comparison of simulation results showed Ziegler_Nichols adjustment method has better performance than Matlab's auto-tune method.

Keywords— PID controller, passive exercises, rehabilitation, autonomous control.

I. INTRODUCTION

Controller design for rehabilitation machines has become important topic since we realized that the rehabilitation machines advantages for therapeutic exercises. Studies about gathering data for controller, controller design and mechanism design for rehabilitation devices are outlined in this section.

Zhou et al. at their works about human motion tracking and human motion tracking for rehabilitation, tested many motion tracking methods and their comparisons proved that inertial sensors is easy to use and they gives high accuracy data for motion tracking [1-6].

Rasyid et al. designed continuous passive motion device. The device designed for shoulder joint. Device can be used after performing an operation or for patients suffering from joint motion limitation because of early stage of frozen shoulder [7]. Mihelj et al. proposed and evaluated a strategy for patient-cooperative control of rehabilitation devices for upper limbs. At their work they used ARMin robot which is exoskeleton robot. While designing the controller, they aimed provide support to patient with minimum intervention. In this way patient can use trajectory what he or she wants while reaching the destination point. Optimizing the trajectory depends on patients self during the therapy. Some patients might never achieve optimal trajectories; however they might still be able to reach the target with adequate robot support. That situation is the goal of their proposed control strategy [8].

Birch et al. designed mobile device for rehabilitation of human hand. That device used either continuous passive motion (CPM) or continuous active motion (CAM) exercises. They used proportional-derivative control for CPM mode. At CPM mode device working with preset waypoints and at CAM mode device actively resist the movement of patient. Device can use for both the MCP and PIP joints. They made this work non-clinic, and they are planning to evaluate this device with rehabilitation professionals [9]. Saputra et al. designed and evaluated automatically working CPM for human knee joint. System stops and turning to beginning point when patients feel pain. They have provided that with using Analog-Digital Converter (ADC). When the DC motor received load, the voltage decrease detected by ADC and after 1.5 seconds motor rotates again with another direction. They used microcontroller to control this system[10]. Dong et al. developed prototype rehabilitation device for controlling human joint movement. They designed intelligent controller that can perform movement to patient which is applied by therapist. That device provides both isometric and isokinetic movements [11]. Hassani et al. developed powered orthotics for helping health staff during rehabilitation and to perform passive and active motions [12]. Human knee joint angle change estimated by Zhang et al. with using BP neural network. Six patients join the experiment to verify the efficiency of neural network. That neural network used in robot design which for active rehabilitation exercises [13].

Designing parallel rehabilitation robot for human ankle movement was proposed by Prashant et al. They discussed optimization problem with using kinematic analysis and genetic algorithm for proposed robot [14]. Wang et al. designed rehabilitation robot for human ankle, knee and hip joints and they discussed stability and dynamic performance of robot. In addition they used swarm algorithm at optimization problem [15]. Lee et al. placed artificial mechanism at human knee joint and they gave mathematical model for that artificial mechanism[16]. Angle change of human hip and knee joint from volunteers measured by Chua et al. and they used that data for designing rehabilitation robot [17]. Yildirim and Eski used vibration data of human hip and knee joints at designing neural network analyzer [18].

Experts about physiotherapy has to decide right therapy exercises that the therapy angles which are suitable for patient and will not exceed the pain limit of patient. Right therapy exercises and angles are unique for patient because it depends on many variable. For this reason therapy exercises decided clinic. Because of the uniqueness of therapy, physiotherapist has to show therapy exercise to therapy system.

In this paper, we designed controller with data's which are taken by using inertial sensors. This controller is tracking exercise trajectories for shoulder joint.
II. DYNAMICS OF HUMAN UPPER LIMBS

There were several different modeling’s including human upper limbs in the literature. In this paper, the assumptions were made that human arm consist of three rigid limbs and have three-degree of freedom. Each of the joints was modeled as one-degree of freedom joint.

Relationship between the external forces and displacements generated by external forces could be expressed by linear transfer function which generally called as mechanic impedance or admittance. Basic linear expression of one DOF (single joint) musculoskeletal system in Laplace domain:

$$\theta(s) = \frac{1}{Is^2 + Bs + K}[T_e(s) + T_m(s)]$$

where $\theta$ is the joint angle, $I$ is the inertia moment, $B$ is the joint viscosity, $K$ is the joint stiffness, $T_e$ is the torque of muscle and $T_m$ is the external torque. Here, the visco-elastic joint features depending on joints itself, visco-elastic features of passive component of muscles and visco-elastic features of activated muscles. The muscles visco-elastic features can be divided into intrinsic system and reflexive system. $B$ and $K$ at Eq. 1 is include intrinsic system features but not include reflexive system. The muscles reflexive torque can be modeled as:

$$T_m(s) = -\frac{\beta_0 s + \beta_1 e^{-\alpha s}}{\alpha s + 1}\theta(s)$$

where $\beta_0$ is the position feedback gain, $\beta_1$ is the velocity feedback gain, $\tau$ is the loop delay and $\alpha$ is the time constant. While using Eq. 1 for calculation of the human dynamics, if the reflexive torque is too small or muscle activation dynamics can be neglected, the joint dynamic equation will be second-order system [19].

Considering muscles are in fully relaxed condition and muscle activity will be nearly zero during the passive therapy exercises, the muscle reflexive torque $T_m$ can be neglected because it will be nearly zero. According to this in Eq. 1 angle only depends on external torque and intrinsic system as Milner et al. [20] and Morita et al. [21] used at their work. So dynamic equations for human joints separately modeled as second-order system is given by:

$$I\ddot{\theta} + b\dot{\theta} + k\theta = T$$

III. SYSTEM MODELLING

For designing controller, firstly we need the dynamic model of shoulder, elbow and wrist joint. We use Eq. 3 and Fig. 1 for modeling human joints.

As you seen in the Fig. 1, Eq. 4 expressed for shoulder joint, Eq. 5 for elbow joint and Eq. 6 for wrist joint. State-space model for Eq. 4-6 is:

$$\dot{x}(t) = Ax(t) + Bu(t)$$

$$y(t) = Cx(t) + Du(t)$$

$$x = \begin{bmatrix} \theta_1 \\ \dot{\theta}_1 \\ \theta_2 \\ \dot{\theta}_2 \\ \theta_3 \\ \dot{\theta}_3 \end{bmatrix}$$

$$u_1 = \begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix}$$
For shoulder, elbow and wrist, dynamic parameters, which for fully relaxed condition and with minimum muscle activity of human extremities, given in Table I [19, 20, 22-24].

### Table I

<table>
<thead>
<tr>
<th>Wrist joint</th>
<th>Elbow joint</th>
<th>Shoulder joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_1$ (Hand)</td>
<td>$B_3$</td>
<td>$K_3$</td>
</tr>
<tr>
<td>0.005 kg/m²</td>
<td>0.003 Nms/rad</td>
<td>3 Nm/rad</td>
</tr>
<tr>
<td>$I_2$ (Forearm)</td>
<td>$B_1$</td>
<td>$K_1$</td>
</tr>
<tr>
<td>0.013 kg/m²</td>
<td>0.2 Nms/rad</td>
<td>2 Nm/rad</td>
</tr>
<tr>
<td>$I_1$ (Upper arm)</td>
<td>$B_2$</td>
<td>$K_2$</td>
</tr>
<tr>
<td>0.015 kg/m²</td>
<td>0.3 Nms/rad</td>
<td>10 Nm/rad</td>
</tr>
</tbody>
</table>

### Table II

<table>
<thead>
<tr>
<th>Control Structures</th>
<th>$K_p$</th>
<th>$K_i$</th>
<th>$K_d$</th>
<th>Filter coefficient (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PID (Tune)</td>
<td>18.31</td>
<td>729.33</td>
<td>0.08</td>
<td>243.3401</td>
</tr>
<tr>
<td>PID (ZN)</td>
<td>90</td>
<td>10</td>
<td>0.5625</td>
<td>-</td>
</tr>
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</table>

### Table III

<table>
<thead>
<tr>
<th>Shoulder joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Structures</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>PID (Tune)</td>
</tr>
<tr>
<td>PID (ZN)</td>
</tr>
</tbody>
</table>

IV. EXPERIMENTAL AND SIMULATION RESULTS

At this section, data which are taken from patients has limitation on shoulder joint and control techniques developed based on these data results are given. According to taken data from patients shoulder joint, PID (Tune) and PID (ZN) control systems are designed. Matlab's PID tuning algorithm and Ziegler-Nichols algorithm are used to adjustment of PID's gain parameters and gain parameter given in Table II Transient state responses of control structures for step input are shown for the shoulder joint at Fig. 2. As seen in Table III, the PID (ZN) control structure has given better results on rise time, settling time and overshoot but steady-state error.

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\[
A = \begin{bmatrix}
K_1 & 0 & 0 & \cdots \\
(1 + I_2 + I_3) & 0 & 0 & \cdots \\
0 & 0 & 0 & \cdots \\
0 & 0 & 0 & \cdots \\
0 & 0 & 0 & \cdots \\
0 & 0 & 0 & \cdots \\
\end{bmatrix}
\]

\[
B = \begin{bmatrix}
1 & 0 & 0 & \cdots \\
(1 + I_2 + I_3) & 0 & 0 & \cdots \\
0 & 0 & 0 & \cdots \\
0 & 0 & 0 & \cdots \\
0 & 0 & 0 & \cdots \\
\end{bmatrix}
\]

\[
C = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 \\
\end{bmatrix}
\]

\[
D = [0]
\]
Simulation results for proposed controllers with patient data’s has shown at Fig.3,4. Data’s taken from patients who has shoulder joint limitation. Patient - 1 is 61 years old male and has limitation at right shoulder joint, Patient - 2 is 62 years old male and has limitation at left shoulder after fracture.

As seen in figures, PID (ZN) has control system has better results than PID (Tune) on formed maximum error during movement.

V. CONCLUSIONS

In this paper, control structure designed according to taken data from patients who has limitation shoulder joint and different physical specifications. According to experimental and simulation results, the PID (ZN) control system is better than PID (Tune) on adapting and it has minimum steady state error. Although, PID (ZN) gives better results than PID (Tune), for future work other intelligent control structures will be simulated and compared with PID (Tune) and PID (ZN) control systems.

ACKNOWLEDGMENT

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REFERENCES


The Realization of a Control Algorithm and its PLC Based Program Able to Authorize Four Different Ranks of Priority to Elevator Users

Mümine YILDIZ*, Mehmet KARALI*

Dept. of Mechatronic Engineering Necmettin Erbakan University, Konya, Turkey

Abstract— Elevator software programs are currently unable to meet the required demand regarding elevator services of high-rise community and government buildings such as hospitals and social centers. Administrators, emergency room doctors and nurses in hospitals; authorities in public or governmental buildings (such as ministers, governors, rectors, deans); or managers, and staff working in community buildings wish privileged use of existing elevators. This isn’t only a personal privilege, but an institutional necessity; resulting in a second elevator assigned to VIP use. Regrettably, while such elevators are empty, others become too crowded and queues form up, resulting in frequent breakdowns. Not to mention the unauthorized use of said elevators causing problems in instances where an emergency is at hand. The solution of card and/or key systems on the other hand has become tedious and inefficient.

In this project, authorization rankings were assigned and special usage privileges given. Thus, in cases where VIP usage is needed, the elevator temporarily cancels out either totally or partially all other calls according to VIP ranking, resulting in the efficient use of elevators by preventing them from being inactive when there is no ongoing VIP usage. Algorithms have been written for authorized use and have been designed for flexible response using PLCs. This project utilizes a model encompassing a four rank authorization system (three VIP, and one normal) which, after a number of simulations, has been tested on a servomotor-powered mechanism. The project is planned to be expanded to incorporate up to a ten rank authorization system.

Keywords— Elevator Control, PLC (Programmable Logic Controller), Privileged Use of Elevators

I. INTRODUCTION

The prime objective sought of elevators is providing services to the maximum amount of users in minimum waiting period [1]. Researchers have utilized different approaches in studies to reach this goal. In [2] the author explained that; an ambient intelligence application that can model a group elevator timing control system was optimized with the help of a fuzzy-artificial immune recognition system. In the designed system, by using the optimization aspect of clonal choice algorithms of the fuzzy-artificial immune recognition system, average waiting periods of users were aimed to be lessened. In [3] the author explained that; the developed system can adapt to traffic in different conditions. As such, it hosts maximum amount of users with minimum waiting periods and takes them to desired floor while also saving energy through this performance. Thanks to expert rule based fuzzy logic supervisors, distinct traffic hours are identified. Relating to this classification more specified fuzzy logic is realized regarding every one of the model classes. In [4] the author explained that; the traffic models in buildings used for various purposes differ. Thus, in order to carry the maximum amount of people in the minimum amount of time, the algorithm for elevator control should be developed with this circumstance in mind. In the elevator system, by monitoring changes in the number and direction of user calls, and through incorporating a suitable control algorithm, the designated goal of carrying maximum people in minimum time was tried to be reached. In [5] the author explained that; this paper describes the development of 2 nine-storey elevators control system for a residential building. The control system adopts PLC as controller, and uses a parallel connection dispatching rule based on “minimum waiting time” to run 2 elevators in parallel mode. In [6] the author explained that; an elevator group supervisory controller is a control system that manages systematically two or more elevators in order to serve passengers as required. The elevator cars are assigned accordingly in response to hall calls, so as to optimize waiting time, riding time, power consumption, passengers’ comfort, etc. In this paper, the simplicity of ordinal structure fuzzy logic in making crucial supervisory control decisions is demonstrated. In addition, in order to further improve the performance, a new approach of ordinal structure fuzzy logic with context adaptation is demonstrated to implement an elevator group supervisory controller for a building with 15 floors and 4 elevator cars. Simulations comparing ordinal structure fuzzy logic algorithm with and without context adaptation, show that the former performs better.

As for this project; elevator traffic density was aimed to be lessened through the formulation of four different algorithms created for four differently ranked priority groups (rank1, rank2, rank3, normal), preventing VIP assigned elevators from being idle while providing for privileged (VIP) users through a password system the use of normal elevators and also allocating the call traffic of normal elevators to encompass all elevators. Problems which arise from the misuse of special purpose elevators in emergency situations were also prevented.
Through a password system, the elevator, in case of VIP usage, temporarily cancels out either totally or partially all other calls and sends the elevator according to VIP ranking of the caller. Elevator Control Algorithms:

1) Rank1 Mode: Being the highest privileged rank, answers the call in fastest manner. All calls before and after are canceled until caller has reached destination.

2) Rank2 Mode: Being a middle privileged rank, elevator answers Rank2 calls while higher privilege still remains with Rank1 calls. It answers cabin calls made before Rank2 call until Rank2 is reached, and answers Rank1 calls made afterwards, and Rank2 and Rank3 calls which are en route.

3) Rank3 Mode: Being a low privileged rank, Rank2 has higher priority. Calls made before Rank3 call are answered until Rank3 user is reached. Afterwards normal calls are not answered.

4) Normal Mode: Being the lowest rank, elevator calls matching elevator direction are answered with accordance to en route closeness, while calls in the opposite direction are answered after elevator course changes again accordingly with en route closeness.

When answering calls with the same priority the rule used for Normal Mode has been determined.

II. ELEVATOR CONTROL DESIGN

A. Hardware and Software

Designed elevator system is composed of mainly three parts; control system, interfacing for elevator system and elevator prototype.

1) Control Parts: Created algorithms were implemented with Panasonic FP-X programmable logic controller (PLC).

PLC's isolation is better than other controller system's isolation, because it is influenced less by temperature changes, moisture, noise and vibration. PLCs can also easily control many components in the market such as sensors, contactors and relays. It is easy to make revision on created systems. PLC devices provide the possibility of remote control. That is, it is possible to control the PLC control system device via the internet.

Panasonic FPX FPW Pro7 software is used to program the PLC. This software can write all FP series’ PLCs programs. It has five programming languages, which are the instruction list, ladder diagram, function block diagram, sequential function chart, and structured text. In this project ladder diagram programming languages are used.

2) Interfacing For Elevator System: For the elevator system human-machine interface, WinTR SCADA was used. Production of this software has begun in 2009 by Fultek, a Turkish company. Among its advantages are that it allows communication between the PLC of many different brands and that it is free for non-profit use.

The SCADA interface allows monitoring the up and down movement of the elevator and the opening and closing of its doors without the use of a prototype and easily testing the developed program and the finding of errors and problems. It is possible to enlarge the system within SCADA without the need for physical hardware.

3) Elevator Prototype: By using a servo motor for the application of experimental studies a prototype elevator has been created. The prototype system design was simplified through position control by taking advantage of the position control feature of the servo motor, without using limit switches. A system that uses a different motor can be easily integrated to this program, since the motor control program was formed as motor control subroutine.

B. Elevator Control Algorithms

1) Normal Mode: Single elevator traffic algorithms used to control the elevator system can be one of the following: Car-switch Operation, Automatic Operation, Signal Operation, and Collective Operation. In this project, Collective Operation Logic, which gives the least wait-time, was used to create the Normal mode algorithm. Collective operation answers same direction calls according to proximity and stores to memory opposite direction calls to be answered after direction change.

Rather than a flow control diagram, a logical solution has been opted via Karnaugh map by evaluating all possible working conditions.

Desired output in line with system logic has been ensured by evaluating the situation between different variables, mainly: the data of the movement of elevator, the directional input of the calls and the proximity of the calls according to one another.

A part of the table showing the output according to the possibility table created according to these variables has been given in Table I.

Output evaluation of the variables has been done as so: If elevator is going up, and if there is an up direction call, and it is also the closest call; then gives output. Every line in the probable situations table is evaluated according to this logic.

The Karnaugh solution which provides the result according to the created conditions is so:

\[ \text{[BCDGE + [BCDGF + B[C][H][GE + B][C][H][GF + AB][C][H][G + A][BCD][G + [BD][H[GE + BD][HGF + A][BD][HG + [BD][GE + [BDH][GF + A][BDH][G}} \]

When the Karnaugh solution is applied to PLC the program is generally formed of the networks where the Karnaugh solution is applied and the networks where the necessary variables are produced. For example, the processes of committing incoming calls to memory and resetting or networks where the closest call proximities can be obtained. The Figure 1 represents this situation.
TABLE I  
TABLE FOR NORMAL MODE OUTPUT CONDITIONS

<table>
<thead>
<tr>
<th>Elevator Down</th>
<th>Elevator Up</th>
<th>Elevator halt</th>
<th>Elevator stop</th>
<th>Down Call</th>
<th>Up Call</th>
<th>Cabin Call</th>
<th>The most appropriate call</th>
<th>Normal mode output</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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</tbody>
</table>

Fig. 1 Process of PLC Program

2) Privileged Modes: By observing the same method to write the Normal mode program, the probable possibilities for Rank1, Rank2, Rank3 have been evaluated according to the required conditions and outputs were obtained. For the obtained results the Karnaugh analysis was used. The program blocks created were combined into an integrated program for four modes.

The transition conditions from normal mode to privileged mode, and from any privileged mode to another rank have been set. When in privileged mode, the collective operation will be used for other calls on the same rank. For example, when in Rank2, another Rank2 call will be accepted if on the way, if not it will be left for later.

2.1) Rank1: When in either Rank2, Rank3 or Normal mode, in order to respond to the Rank1 call, the elevator stops on the nearest floor and an announcement is made for the passengers to evacuate the elevator. Then, the elevator goes directly to the Rank1 user and performs the cabin call for Rank1 users. No calls other than another Rank1 call are accepted. When in Rank1, collective operation logic is used for incoming Rank1 calls. After the Rank1 call has been fulfilled, the elevator returns to Normal mode if there are no other Rank1 calls.
2.2) Rank2: When in Normal mode, the cabin calls before the Rank2 call will be performed, other floor calls will be canceled. After reaching Rank2 user, no calls other than Rank1 and Rank2 will be accepted. When in Rank2, collective operation logic is used for incoming Rank2 calls.

2.3) Rank3: When in Normal mode, all calls before the Rank3 call will be performed until the Rank3 user is reached. In Rank3, only Normal calls will not be accepted. If there is an incoming Rank2 call during Rank3 mode, the Rank3 user will be dropped off on a requested floor if it is en route. If in the opposite direction, the user will be dropped off at the nearest floor.

<table>
<thead>
<tr>
<th>TABLE II</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPARISON OF PRIORITY USER RANKINGS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Rank1</th>
<th>Rank2</th>
<th>Rank3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cancels floor calls made before</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Cancels cabin calls made before</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Accepts Rank1 calls made afterwards</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Accepts Rank2 calls made afterwards</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Accepts Rank3 calls made afterwards</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Accepts Normal calls made afterwards</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

C. Results

In this study, by transforming privileged-use-only elevators into normal-use elevators, the traffic density on normal-use elevators has been distributed among all elevators, thus reducing elevator traffic. Furthermore, a PLC based controller has been added allowing four different ranks of privileged use with password. Elevator flexibility and a lower-cost solution for special use and possible emergency situations have been achieved through privileged use.

The created algorithms have been tested on the designed simulation program and prototype. Below is a scenario for testing and a simulation interface where the scenario movement can be observed.

Figure2: When elevator is on the 5th floor, an upwards call from the 2nd floor and a downwards call from the 3rd floor comes.

Figure3: When elevator reaches the 3rd floor, a cabin call from ground floor and a downwards call from the 2nd floor comes.

Figure4: The figure shows the elevator downwards movement to answer cabin call from ground floor.
Figure 5: After elevator reaches the 2nd floor, it takes cabin call from the 4th floor. It starts to move. It halts on the 3rd floor and it moves the 4th floor.

In the following studies, it is planned to increase the number of ranks of privileged use, and to add privileged use to group elevator systems.

REFERENCES

Analysis of Suspension System for 3D Printed Mobile Robot

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Abstract—In this study, 3D printed mobile robot with suspension system was analysed using Computer Aided Engineering (CAE) methods. Spring and damping coefficients of the suspension system were determined. Structural and dynamic analyses were conducted after the selection of appropriate spring and damping coefficients to find structural strength and power requirement of mobile robot. The length of robot and the number of wheels were decreased to one third of the real to ease the analysis. A concrete road with the length of 1,000 mm and 10° inclination was created as ground to simulate the real world. Obstacles with the height of 80 mm were placed on different locations on the path of the wheels for the robot. The designed suspension system was consisted of; two dashpots connected to wheels and body through connecting components and a spring between two wheels to ensure the stability. Polylactic acid (PLA) was used as body material. In the structural part; the strength of the robot body and critical part (suspension leg) was computed by Finite Element Analysis (FEA). Safety factor values for body and critical component were found as almost 7 and 4, respectively. It was obtained from the analysis results that maximum equivalent stresses and strains (for body $\sigma_{max} = 3.4$ MPa, $\varepsilon_{max} = 3 \times 10^{-3}$ mm/mm and for critical component $\sigma_{max} = 6.5$ MPa, $\varepsilon_{max} = 6 \times 10^{-3}$ mm/mm) were occurred while robot was passing the obstacles. In dynamic analysis; robot was driven with three different speeds (0.25, 0.5 and 1 metre per second) on the same road conditions. The motor torque and force values, suspension system results (force and elongation), angular velocity of the wheels and power requirement of mobile robot were calculated. The results showed the power requirement of robot is 70 Watt when it is driven with maximum velocity.

Keywords—Computer Aided Engineering, Finite Element Analysis, Polylactic Acid, Suspension System, 3D Printed Mobile Robot

I. INTRODUCTION

Robots are increasingly entering the area of many technical studies and research. Recently; robotic industry is improving and evolving rapidly to satisfy the needs of markets, daily use of people, manufacturing, research projects and universities etc. [1].

Mobile robot is one of the most common type of robotic types. A mobile robot has unlimited movement to complete its mission. They can be used to perform a variety of tasks normally carried out by humans such as surveillance, exploration, patrol, fire searching-fighting, homeland security and care taker etc. [2].

A mobile robot system consists of a platform moved by locomotive elements. The locomotive system depends firstly on the environment that the robot operates. These environment can be aerial, aquatic and terrestrial. In the aquatic and aerial environments, the locomotive systems are generally propellers or screws. The locomotive system in terrestrial environment is complicated. Wheels, tracks and legs are the typical terrestrial locomotive elements [3].

Different types of suspension systems are used for mobile robots that operates at terrestrial environment to ease the adoption to usage area and to increase the flexibility and motion ability. Suspension systems of mobile robots are generally designed and produced using dashpots, return and compressing springs.

Rapid prototyping techniques are nowadays used in product development process. They allow for fast, low-cost and easy manufacturing series of components directly from the the component geometry stored in CAD model. This prototyping process allows for assessment of many aspects of functionality, dimensional, physical and esthetical adaptation of components in the developed product [4]. 3D printing technology is one of the most common types of rapid prototyping techniques. As 3D printers become more prevalent among users they are being used to manufacture more diverse objects. This has included components that either replace items normally purchased or are uniquely designed for the specific needs of the user in terms of geometry and function [5].

It is an easy and low-cost way of using 3D printing technology to produce the components of a mobile robot prototype. After CAD and CAE process; mobile robot for any environment can be created and checked for final product. It is a great way for designers and researcher to decrease the modelling and manufacturing time and cost. 3D printing technology opens a new way with the advantages summarized below [6]:

- Fast prototyping for mobile robot platforms
- Decreasing the time and cost of modelling and manufacturing
- Easy configuration and adaptation
- Motivation for the development of new types of products

In this article we focused on the development of 3D printed mobile robot with suspension system. After design process; solid state model of mobile robot was analysed using Computer Aided Engineering (CAE) methods. Spring and...
damping coefficients of the suspension system were determined. Structural and dynamic analyses were conducted. Important design and manufacturing parameters were determined using analyses and real world test results.

II. DESIGN OF 3D PRINTED MOBILE ROBOT

Mobile robot (Fig. 1) was designed using CAD tools. In the design process; several issues were considered such as compact size, modularity, time and cost. The most important point of the design was compliance with additive manufacturing technique for all of the components except wheels, electric motors and suspension system. Body and connection components were produced using 3D printing technology. The sizes, thickness, shape of the parts were taken into consideration that affect the manufacturing process using 3D printer. Complexity of the components were decreased to save time-material and to improve the robot’s performance.

![Fig. 1 Designed 3D printed off-road mobile robot](image)

A. Geometry and 3D Model

All of the parts of the robot were prepared using parametric solid modelling technique. The required connectors, channels and supports for the wheels, electric motors and suspension components were designed using technical data sheet and drawings. The assembly model was created and compatibility of the manufactured parts and commercially available components were checked in assembly model. Designed off-road mobile robot has six independent wheel-motor-suspension systems. The details of the traction system for the mobile robot are depicted in Fig. 2, Table I.

![Fig. 2 Exploded view of mobile robot traction system](image)

<table>
<thead>
<tr>
<th>Number</th>
<th>Component Name</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sub chassis</td>
<td>It is bottom body of the mobile robot.</td>
</tr>
<tr>
<td>2</td>
<td>Body connector</td>
<td>Body connectors are used for suspension leg-chassis connections.</td>
</tr>
<tr>
<td>3</td>
<td>Connection screw</td>
<td>Different types of screws are used for connection and suspension motions.</td>
</tr>
<tr>
<td>4</td>
<td>Suspension Leg</td>
<td>It is the critical part of the robot suspension system. The mobility of the suspension system is provided with suspension leg.</td>
</tr>
<tr>
<td>5</td>
<td>Wheel</td>
<td>It is for the motion of mobile robot.</td>
</tr>
<tr>
<td>6</td>
<td>Wheel-motor connector</td>
<td>It is used as shaft between motor and wheel.</td>
</tr>
<tr>
<td>7</td>
<td>Wheel-case connector</td>
<td>It is for the connection between wheel and motor protection case.</td>
</tr>
<tr>
<td>8</td>
<td>Electric motor</td>
<td>It is used for actuation.</td>
</tr>
<tr>
<td>9</td>
<td>Motor case</td>
<td>As the robot is designed as off-road, motor protection case is designed and manufactured.</td>
</tr>
<tr>
<td>10</td>
<td>Dashpot</td>
<td>It is suspension system element. The robot can climb and pass the obstacles using this component.</td>
</tr>
<tr>
<td>11</td>
<td>Dashpot-body connector</td>
<td>It is for suspension system-body connection.</td>
</tr>
</tbody>
</table>

B. Suspension System Design

3D printed mobile robot was designed and manufactured as off-road vehicle prototype. So the suspension system was most critical for the operation at challenging terrain. It should be optimized for body stability, to improve the motion capability and to decrease the energy consumption.

For the suspension six dashpots and three return springs were used. Dashpots, were connected between wheel legs and body to climb and pass the obstacles. Springs were placed between wheels horizontally for motion and body stability.
Spring and damping coefficients were determined using catalogue values. The total weight of the robot was about 6 kg so load for each wheel was 1 kg. Using this information and catalogue values 5 different spring and damping coefficients were applied at Matlab Simulink simulation environment. (For Sys1; k=150N/m b=50 Ns/m, Sys2; k=250N/m b=75 Ns/m, Sys3; k=350N/m b=100 Ns/m, Sys4; k=750N/m b=125 Ns/m, Sys5; k=1,000N/m b=150 Ns/m). The optimum coefficient values were determined as 350 N/m and 100 Ns/mm for spring and damping respectively for flexibility and stability.

Using these coefficients; dashpots and springs were selected easily. The length of the aluminium dashpot shown in Fig. 3 was 11 cm that provides capability to the robot to pass the obstacles up to 10 cm without climbing.

Fig. 3 Selected dashpot for robot suspension system

C. Material of Mobile Robot

Rapid Prototyping Systems produce objects generally from acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA). These materials have low enough melting temperatures to use in melt extrusion in a dedicated machine and high enough temperature for prints to retain their shape at average use temperatures [7].

Usually, plastics as PLA or ABS are used as raw material to feed 3D printers. However, environmental pollution made by plastics is a real problem to solve. For that reason, PLA is used more and more. It is biodegradable, thermoplastic and semi crystalline [8].

ABS; strength, flexibility, machinability, and higher temperature resistance make it often a preferred plastic for engineers, and professional applications. It is strong, flexible, with good machinability and a higher temperature resistance. These properties can make it more popular for use in professional applications. PLA; the wide range of available colours and translucencies attract those who print for display or general uses. When properly cooled, PLA seems to have higher maximum printing speeds, lower layer heights, and sharper printed corners. Combining this with low fault on parts make it a popular plastic for general printers, hobbyists, and schools [9]. Mechanical properties of PLA and ABS are given in Table II.

D. Manufacturing of Mobile Robot

All of the parts of mobile robot; connectors, suspension legs, bodies, motor-electronic protection cases and body shell were designed and manufactured using 3D printing technology and PLA material (Fig. 4). The weight of manufactured parts and commercially available components (wheels, motors, suspension elements and connection screws) were about 3.5 and 2.5 kg respectively. As a result an off-road light weight mobile robot prototype with 6 kg was designed and manufactured.

![Fig. 4 3D printing technology (a) 3d printer (b) PLA filament](image)
III. STRUCTURAL ANALYSIS

Structural analysis was conducted after the selection of suitable material, spring and damping coefficients to find structural strength for whole robot's body and critical components using Ansys Workbench Static Structural Module. Safety factors, maximum equivalent stresses and strains for whole body and critical component (suspension leg) were calculated.

The length of robot and number of wheels were decreased to one third of the real to ease the analysis. A concrete road with the length of 1,000 mm and 10° inclination was created as ground to simulate the real world. Obstacles with height of 80 mm were placed on different locations on the path of the wheels for the robot. The strength of the robot body and critical part was performed by Finite Element Analysis (FEA).

In the first part of structural analysis (Fig. 5); static loads were applied to mobile robot. These loads were; self-weight of the robot about 2.5 kg, other suppressed weights such as battery and electronic protection case (1.5 kg) and the forces caused by suspension leg motion while it was passing the obstacles.

A crash analysis was carried out with 1 and 2 m/s velocities in the second part of structural analysis (Fig. 6) Although the maximum speed of the robot was 1 m/s twice more impact force was applied because of slow down distance effect and for safety. The impact forces were calculated with formula shown below.

\[ F_s = \frac{1}{2} m \times V^2 \]  
\[ F = \frac{1}{2} m \times V^2 \times \frac{s}{s} \]  

Where:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>Fs</td>
<td>Slow down force (N)</td>
</tr>
<tr>
<td>F</td>
<td>Impact force (N)</td>
</tr>
<tr>
<td>m</td>
<td>Mass (kg)</td>
</tr>
<tr>
<td>V</td>
<td>Velocity (m/s)</td>
</tr>
<tr>
<td>s</td>
<td>Slow down distance (m)</td>
</tr>
</tbody>
</table>

Slow down distance was assumed as 8 mm using experimental application. Using the formula (1) and (2), the impact forces were calculated for 1 and 2 m/s velocities;

\[ F_s = \frac{1}{2} m \times V^2 / s = 1/2 \times 4 \times 1^2 / 0.008 = 250 \, N \]  
\[ F = \frac{1}{2} m \times V^2 / s = 1/2 \times 4 \times 2^2 / 0.008 = 500 \, N \]  

IV. DYNAMIC ANALYSIS

Dynamic analysis was carried out using Ansys Workbench Rigid Dynamics Module. Mobile robot was driven with three different speeds (0.25, 0.5 and 1 metre per second) on the same road condition with structural analysis. Rotational velocities were defined to wheels to create the displacement motion. Suspension leg connections were assigned as rotary joints. Joint loads were applied 50° to pass the placed obstacles. The required information for motor selection; torque and force values, suspension system results (occurred force and elongation), angular velocity of the wheels and power requirement of mobile robot was calculated in dynamic analysis (Fig. 7).

V. RESULTS AND DISCUSSION

A. Structural Analysis

Structural analysis results under static loads are given in Table III.
TABLE III
STRUCTURAL ANALYSIS RESULTS UNDER STATIC LOADS

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent stress body (MPa)</td>
<td>3.5</td>
</tr>
<tr>
<td>Equivalent stress critical component (MPa)</td>
<td>6.5</td>
</tr>
<tr>
<td>Equivalent strain body (mm/mm)</td>
<td>0.003</td>
</tr>
<tr>
<td>Equivalent strain critical component (mm/mm)</td>
<td>0.006</td>
</tr>
<tr>
<td>Safety factor for whole body</td>
<td>7</td>
</tr>
<tr>
<td>Safety factor for critical component</td>
<td>4</td>
</tr>
</tbody>
</table>

The total calculated maximum equivalent stresses for whole body and critical components were found about 3.5 and 6.5 MPa respectively. The calculated stresses are not overcome the strength of PLA material. Safety factor values for both body and critical components (7 for whole body 4 for critical component) showed that robot can operate under static loads safely. However, mobile robot’s prototype was designed for off-road operation. To get more reliable results; crash analysis with calculated impact force was conducted in structural analysis. 250 and 500 N forces were applied to robot front wheels to create the crash simulation.

Crash analysis results with 250 and 500 N impact forces are given in Table IV.

TABLE IV
CRASH ANALYSIS RESULTS

<table>
<thead>
<tr>
<th>Criteria</th>
<th>250 N</th>
<th>500 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equivalent stress body (MPa)</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Equivalent stress critical component (MPa)</td>
<td>13</td>
<td>27</td>
</tr>
<tr>
<td>Equivalent strain body (mm/mm)</td>
<td>0.004</td>
<td>0.01</td>
</tr>
<tr>
<td>Equivalent strain critical component (mm/mm)</td>
<td>0.012</td>
<td>0.024</td>
</tr>
<tr>
<td>Safety factor for whole body</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Safety factor for critical component</td>
<td>2</td>
<td>0.9</td>
</tr>
</tbody>
</table>

As understood from the results that equivalent stresses caused by 250 and 500 N impact forces were almost twice and four times greater than occurred stresses with static loads for critical component. The calculated safety factor decreased from 4 to 2 with 250 N that arose from 1 m/s velocity crash.

The safety factor was found as 0.9 with 2m/s velocity crash. It can be understood that this component was broken with this applied speed. Critical component is not strong enough for crash scenario occurred with 2 m/s velocity. Crash test was also applied in real world application. It was observed that both in analysis and real world; suspension leg was broken at similar area (Fig. 8).

B. Dynamic Analysis

The power requirement of mobile robot was found as 18, 35 and 71Watt for 0.25, 0.5 and 1 m/s speeds. As the number of wheels and length of robot were decreased to one third of the real to ease the analysis the calculated power requirement was for one third of whole system. The total power requirement is about 213 Watt.

Using these information electric motors were selected with the values of 6 volt voltage and 6.2 ampere maximum current. Using 6 electric motors system can supply 223 Watt power and it is sufficient for calculated power requirement.

The other results of dynamic analysis are given in Table V. Dashpot and spring forces-elongations were found as 14 N-42 mm and 2.5 N and 7 N. Maximum torque requirements for electric motor were about 528, 618 and 1,000 N.mm for 0.25, 0.5 and 1 m/s speed values.
VI. CONCLUSION

In this study, 3D printed off-road mobile robot prototype with suspension system was designed and analysed using Computer Aided Engineering (CAE) methods. Spring and damping coefficients of the suspension system were determined. Structural and dynamic analyses were conducted to find structural strength and power requirement of mobile robot. After design and analysis stages body and connection components of mobile robot prototype were manufactured using 3D printing technology. The selected results obtained from analyses and real world application were presented. The safety factor of whole body and critical component were calculated as 5 and 2 in crash analysis with 250 N impact force that occurred when robot is driven with 1 m/s velocity. It can be concluded that the structural material (PLA) could ensure the safety when robot is charged with 250 N impact force.

<table>
<thead>
<tr>
<th>TABLE V</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DYNAMIC ANALYSIS RESULTS</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Criteria</th>
<th>0.25 m/s</th>
<th>0.5 m/s</th>
<th>1 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power requirement (Watt)</td>
<td>18</td>
<td>35</td>
<td>71</td>
</tr>
<tr>
<td>Dashpot force (N)</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Dashpot elongation (mm)</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Spring force (N)</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Spring elongation (mm)</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Motor force (N)</td>
<td>8</td>
<td>8.7</td>
<td>9.5</td>
</tr>
<tr>
<td>Motor torque (N.mm)</td>
<td>528</td>
<td>618</td>
<td>1,000</td>
</tr>
<tr>
<td>Angular velocity (rad/s)</td>
<td>0.38</td>
<td>0.78</td>
<td>1.5</td>
</tr>
</tbody>
</table>

REFERENCES


Modelling and Control of a Single-Wheel Inverted Pendulum by Using Adams and Matlab

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Abstract—This research is aimed at developing a multi-body simulation model and balancing control of a single-wheel inverted pendulum. A virtual prototype of the system has been built by using Adams software and it is simulated in both Matlab and Adams software together. The Adams model has two inputs (disturbance and control) and two outputs (pendulum angle and wheel position). Proportional-integral-derivative (PID) controller is designed and applied in order to use balancing control simulation of pendulum angle. The modelling and control results show that the Proportional-integral-derivative (PID) controller can successfully achieve balancing control of the single-wheeled inverted pendulum. Also this paper can make an important contribution to background of two-wheeled robots, self-balancing transportation devices.

Keywords—PID Control, Modelling, Simulation, Self-Balancing, Single-wheel inverted pendulum.

I. INTRODUCTION

During the recent years, robots have become a basic and time-honoured practice for proving a variety of control systems and control theories. Thanks to their flexible and basic structures, two wheeled self-balancing robots perform well in poor work conditions and complex tasks (space explorations, topographical survey, dangerous goods transportation etc.). Also they can provide safe transportation for both goods and persons thanks to high mobility and rapid response abilities [1].

One and two wheeled self-balancing robots have been started to be seen in literature by 2000s and became more popular nowadays. Due to the fact that they have characteristics as multiple variability, nonlinearity and instability, they have chosen as an important field of study by researchers working on control theory. Stability, durability and controllability of a system can be easily examined with one-wheeled self-balancing robots [2-3].

One-wheeled self-balancing systems are consisting of a mobile robot and an inverted pendulum system. Since it is driven with two coaxial and independently controllable motors, movement of the system is not stable. In order to sense the acceleration along the vertical axis, gyroscope and accelerometer are used in these kinds of systems. In order to make the inverted pendulum stable both when it is on the move and steady, torque signals are generated and transmitted to motors [4-5].

Park and Jung designed a single-wheel mobile robot called GYROBO. They used remote control and sensors in order to both navigate and balance the robot. With PD controller and sensors (gyro, tilt and encoder), GYROBO was able to balance itself and follow the specified trajectory [6]. Cieslak et al. designed and built an one-wheel robot. They mainly focused on self-stabilisation problem and achieved the dynamic stability achieved [7]. Lee at al. designed a single-wheel inverted pendulum system. System was consist of a dc motor and two ducked fans. Pitch angle of system was controlled by dc motor and PD controller. Roll angle was regulated by PID controller and air pressure generated from fans [8]. In his study, Wang applied PID controller to stabilization control of different types of inverted pendulum. Study shows that PID controllers are very effective in this kind of systems [9]. There are similar studies which are conducted on two-wheel systems. Felix et al. designed a two-wheel self-balancing robot called JOE. In order to control this robot, they designed two independent space state models and made the system stand in balance successfully [10]. Wei and Yangmin Li designed PID controller and Linear Quadratic Regulator (LQR) controller and the system was simulated in Matlab, then these two controller methods were applied and results were compared [11]. Kalyoncu et al designed artificial neural network and fuzzy logic based (ANN+F) controller in order to control a two-wheeled robot. After that system was simulated in Matlab/Simulink and results were compared [12].

This paper presents developing a multi-body simulation model and balancing control of a single-wheeled inverted pendulum. An approximation model of the system is modelled by using Adams software. The Adams model has two inputs (disturbance and control) and two outputs (pendulum angle and wheel position) respectively. Where, pendulum angle which is the most important parameter needs to be controlled issued as feedback. Proportional-integral-derivative (PID) controller is designed and implemented for the purpose of balancing control of pendulum angle. Controller design procedure and controller efficiency are shown with graphics. One can understand that single-wheel inverted pendulum system can be simulated and controlled in Adams and Matlab.
II. MODELLING AND CONTROL

Modelling and controlling strategy and system model can be seen in Fig 1. To obtain the dynamic model of single-wheeled inverted pendulum, Adams software is used. Boundary conditions and dynamic loadings are performed in Adams. Thus, more realistic model is derived. Besides this, it is very important to Adams cooperate with Matlab.

![Fig. 1 Strategy of study and system model](image)

Single-wheeled inverted pendulum is able to move in only x direction. Inverted pendulum system is firstly modelled in Adams. System has two inputs (control and disturbance) and two outputs (pendulum angle and wheel position). Necessary boundary conditions like as connections, friction and movement etc. are defined in Adams. System parameters and boundary conditions can be seen in Table 1. Then, created system is exported to Matlab in order to perform controller design works in this software.

![Fig. 2 Block diagram of the system](image)

Time, direction and magnitude of disturbance force is determined and applied to top of the pendulum. 10 N impulse force is applied to pendulum in 1st second of simulation time through – x direction and then another 10 N impulse force is applied in 3rd second of simulation time through the opposite direction. The controller is always active during simulation period. Signal applied as disturbance can be seen in Fig 3.

![Fig. 3 Disturbance signal](image)

III. RESULTS AND DISCUSSIONS

Uncontrolled and controlled responses of the system are analysed after PID controller is designed. Uncontrolled pendulum angle and wheel position responses of the system under the disturbance force can be seen in Fig 4 and Fig 5. As seen in Fig 4, uncontrolled pendulum angle has oscillation under the disturbance force. However the displacement of wheel position is very low since there is friction between wheel and ground. Same result is seen in Adams simulation, also.

![Fig. 4 Pendulum angle of uncontrolled system](image)

**TABLE I**

<table>
<thead>
<tr>
<th>Properties of Pendulum and Wheel</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>M - Mass of the wheel</td>
<td>0.153 kg</td>
</tr>
<tr>
<td>m - Mass of the pendulum</td>
<td>0.2 kg</td>
</tr>
<tr>
<td>l - Pendulum length</td>
<td>0.12 m</td>
</tr>
<tr>
<td>l_p - Pendulum mass moment of inertia</td>
<td>1.3x10^3 kg.m^2</td>
</tr>
<tr>
<td>l_w - Wheel mass moment of inertia</td>
<td>1.85x10^3 kg.m^2</td>
</tr>
<tr>
<td>R - Wheel radius</td>
<td>0.05 m</td>
</tr>
<tr>
<td>T - Torque applied to the wheel</td>
<td>N.m</td>
</tr>
<tr>
<td>θ - Pendulum angle</td>
<td>degree</td>
</tr>
<tr>
<td>μs - Static column friction</td>
<td>0.8</td>
</tr>
<tr>
<td>μd - Dynamic column friction</td>
<td>0.3</td>
</tr>
</tbody>
</table>

General block diagram including system modelling and controller design can be seen in Fig 2. System is a MIMO (multiple input - multiple output) structure which consist of two inputs and two outputs. Inputs are defined as controller (torque, N.m) and disturbance (force, N). Similarly, outputs are defined as pendulum angle (deg) and wheel position (m). Here, pendulum angle which is the most important parameter needs to be controlled issued as feedback. Wheel position is analysed in order to view only motion trajectory.
Then, controlled system responses and simulation studies are analysed. Since system is nonlinear, PID coefficients are obtained by trial and error method. After trials, gains were defined as $K_p=-4$, $K_i=-0.02$ ve $K_d=-2.5$ for this study. Pendulum angle and wheel position responses of the system with PID controller can be seen in Fig 6 and Fig 7.

In order to make the system stable, necessary torque driven by controller can be seen in Fig 8.

**IV. CONCLUSIONS**

There is a lack of knowledge in simulating and controlling the one or more wheel inverted pendulum systems with Adams and Matlab. In this paper, it is shown that single-wheel inverted pendulum system can be simulated and controlled in Adams and Matlab. Also, for future works, this study forms a basis for simulation and control of one or more wheel self-balancing systems.

These kinds of systems have nonlinear characteristics. Efficiency of the software solutions is very important in developing realistic approaches to such kind of systems. In this study, it is shown that Matlab and Adams are efficient in simulating and controlling the nonlinear systems like inverted pendulums.

In this study, pendulum angle of a single-wheel inverted pendulum system is controlled under necessary boundary conditions. Controller design procedure and controller efficiency are shown with graphics. Also, necessary torque values are given in graphics. In this way, design parameters and required equipments for future works and experimental studies are determined.

**REFERENCES**


Analysis of Mechanical Properties of Shape Memory Alloys

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Abstract—In this study, a particular mechanism is designed to obtain the mechanical properties of shape memory alloys (SMA). Mechanical behaviour occurring due to the super elastic properties is investigated by applying current to shape memory alloys via designed mechanism. Displacement, velocity, time, force physical effects of SMA springs is obtained for different current values, and active operating range of springs is determined. This acquired data are of importance in determining the area of use of shape-memory alloys.

This paper presents the structure of the designed mechanism, and datas of mechanical properties of shape memory alloys which is obtained by using this designed mechanism.

Keywords—SMA, Shape Memory Alloy, Super elastic, Actuator

I. INTRODUCTION

Shape Memory Alloy (SMA) is a term given to alloy group which have the ability to return to a predetermined shape or size when it exposed to heat [1].

Nowadays, smart materials are used extensively for industrial applications in the world. Shape memory alloys, which are located in the smart materials, have been investigated in terms of industrial applications in Turkey. They own up to %8 super elastic mechanical properties and this specification has attracted attention of the industry.

Shape memory alloys conserve their deformation shape at room temperature which transistives at high temperature. When electric current is applied to SMA, it heats and transforms from deformed shape to original shape. Shape memory alloys are used in many industrial field such as health, automotive, defence etc. SMA provides superiority in terms of more flexible, lightweight and miniaturization with shape memory effect. These superiorities ensure great advantages for developing of power transmission organs [2].

As a result of deformation of the shape memory alloy can return to its previous form with minimum work and it presents a new perspective that power output throughout phase conversion and power/weight ratio are more than other power transmission organs [3].

Advantages of actuators which are made of Shape memory alloys among other actuators;
• Quite and smooth operation in the smooth system
• Power/weight ratio is in desired level
• Steady state
• Engine with low energy

Shape memory alloys are functional materials because of their martensite transformation and converse transformation such as shape memory effect and super elasticity. Their basic characteristics are that they have two different shape and crystal structure under and above critical transformation temperature. These materials which could be deformed at relatively low temperatures could be return prior to their shape at higher temperatures [4].

Shape memory effect or shape memory issue is that at the main phase shape memory alloy which have a specific shape is cooled to the martensitic transformation temperature and changed the shape with outer impact and after this material return its first shape with increasing the temperature to the main phase temperature.

Fig. 2. Mechanism of memory function (a) austenite phase (b) transformation martensite phase (Mf) (c) deformation (d) transformation austenite phase (Af)

At the Fig. 2.a material’s internal shape transform to martensitic phase (Fig. 2.b) from austenite when it is cooled. At this temperature permanent shape deformation is given to the
material (Fig. 2.c). And this material is transformed into austenite phase when it is heated (Fig. 2.d).

In this study, an experimental set-up is developed to observe physical impacts such as depletion, force, velocity related to shape memory alloys’ super elasticity mechanical properties throughout shape memory alloys’ cooling and heating process [5].

II. DESIGN OF EXPERIMENTAL SET-UP

Obtaining properly material characteristics of titanium and nickel alloys, which is known NiTiNol in industry, have importance since they are widely used to produce biomedical applications and actuators, thus to know their mechanical properties is important to carry out numerical and analytical analysis and simulations. In addition to knowing the relationship between the estimated number of cycles and maximum permissible stress and strain.

In this way, to get mechanical findings two linear actuator is designed as an experimental set-up. With this set-up is aimed to be guide for determining the mechanical behaviour of the shape memory springs.

Shape memory alloys’ mechanical behaviour have great importance to design valve, actuator, mechanical muscle etc. and to investigate new industrial applications.

To obtain the purposed results, two different experimental set-up is designed.

A. Experimental Set-Up

Shape memory alloy behaviour to be tested in the set-up are measured by the Module-1 and Module-2 which are operated as an actuator. Shape memory springs are heated by electric current. High level current is necessary for deformation of springs because of that insulation is provided in areas where contact springs.

At the Fig. 3., experimental set up is observed which was designed to determine characteristic structures of the shape memory alloys.

Experimental set up works based on the principle of the linear actuator and its power supply is provided max. 5.5 A.

Fig. 4. Schematic of the control unit structure

Fig. 4. shows control unit structure for experimental set-up. There is a switch and it has module-1 and module-2. With this switch module is determined to be studied. Also running direction of the working module is also selected with the using key.

The cables used in the control unit is selected to be high current resistant.

C. Module-1

The purpose of Module-1 set-up is to examine the parabolic movement in the horizontal plane of an object which is have 1,2 kg weight. This object is moved under favour of shape memory springs which are mounted on the right and left plane of the object.

To be able to move the object, 2.5 to 5.5A current is respectively applied to both of the shape memory alloy springs which are the right and left plane.

Module-1 is designed to work of the SMA spring that it runs on the horizontal axis with the movable object weight of 1.2 kg. This mechanism is used shape memory springs which are have same mechanical properties and same number of turn. Movable object is positioned at the exact plane. Shape memory springs were stretched by the deformation to maintain a position in which the object is located. A pen is added in front of the movable object.

The experimental setup is powered with the help of designed control panel. Module-1 is activated from the control panel. The process is started by module-1 way according to the direction of the desired position right or left-positioning. When the system runs in the right direction, the SMA spring at right side will return to its original position with the shape memory effect. The same issue applies to work in the left direction of the object. This time the system is operated in the left direction when the system runs in the left direction and SMA spring return its original position with the shape memory effect.

Parabolic actions are scratching in the millimetres paper and these actions are measured. To analyze of the SMA spring

B. Control Unit
behaviour, system is exposed to electric current respectively 5.5 A, 5 A, 4.5 A, 4 A, 3.5 A, 3 A, 2.5 A at the right or left position, during the 10 s, 15 s and 20 s.

At the Fig. 7., scratching object movements are shown. These scratching are plotted during the 10s, 15s, 20s and between 2.5 A- 5.5 A electric current in the range of 0.5A. Thus, depending on the different times and different electric current ranges, SMA spring behaviour are observed and mechanical behaviour datas are recorded.

Fig. 6. shows the velocity gradient according to using electric current to SMA springs. It is shown that, when applied current is increased, SMA spring velocity is increased. According to Fig. 6., the highest acceleration and speed is identified in the 10s.

**D. Module-2**

A cylinder mechanism is designed with SMA spring for module-2. The purpose of this cylinder mechanism is to examine obtaining velocity in consequence of time-depletion datas. These datas are obtained by two SMA springs, which have same mechanical behaviour and different number of turn, 2.5A and 5.5A current range of working.

At this module, SMA springs have been used in different numbers with the same characteristics. One of the spring in the system is pulled and another one is pushed in the process. Because of the used cylinder length is fixed equal number springs are limited the movement of the piston. Therefore, using different number of turn is increased measurement distance and provided maximum extension.

Module-2 is activated from the control panel. The process is started by module-2 according to the direction of the desired position forward or back-positioning. For forward movement, switch is selected “right” position and it moves advanced end position.

For back movement switch is selected “left” position and cylinder moves its back end position. To analyze the SMA spring behaviour, system is exposed to electric current respectively 5.5 A, 5 A, 4.5 A, 4 A, 3.5 A, 3 A, 2.5 A at the right or left position, during the 10 s, 15 s and 20 s.
Fig. 8. shows the velocity gradient according to using electric current to SMA springs.

Speed differences at the forward and back movement are occurred for different number of turn of SMA springs.

III. CONCLUSIONS

In this study, an experimental set-up is developed to determine mechanical and working properties of the SMA that have great importance for industrial applications. By using experimental set-up, SMA materials are tested which have different number of turn and have same mechanical properties. Set-up successfully measured shape memory springs’ behaviour at the different electric current.

This study presents that the velocity of the SMA spring is proportional with applied electric current. With the increase of the applied current value, temperature of the springs increases and springs return their original shapes more quickly. Module-1 experiments are helpful to determine optimum working times. Module-2 experiments is shown that in addition of the current value, number of spring turn is decisive for spring velocity.

REFERENCES

Two-Dimensional Sensor Localization Using Different Types of Distributed Sensor Networks

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Abstract— Wireless Sensor Network (WSN) refers to a group of locationally dispensed and dedicated sensors for observing and recording the physical conditions of the environment and coordinating the aggregated data at a central location. To serve such new applications, localization is largely used in WSNs to define the current location of the sensor nodes. Time of Arrival (ToA) localization is one of the prevalent schemes due to its high estimation accuracy. ToA is a method to estimate the location of a target based on the correlation of the signals and calculating the distances from each anchor to the target by multiplying the speed of light and the time at which the signal is received. In our recent study, we propose Modified 3N algorithm in both 2D and 3D spaces. In the Modified 3N algorithm in 2D, three circles were used and in the Modified 3N algorithm in 3D four spheres were used to localize the target nodes in the network. In this paper, we use Normal, Beta, Weibull and Generalized Pareto distributed networks for localization and the localization performance of the networks are evaluated and compared using MATLAB simulations.

Keywords— Wireless Sensor Networks, Localization, Time of Arrival, Statistical Distributions, Modified 3N Algorithm

I. INTRODUCTION

In recent years, wireless sensors networks (WSNs) have allured considerable interest in numerous fields including disaster alarm, health, military, environment, building, car, and mining industries. They also have remarkable potential to ease our daily life activities. The deployment of sensors is based on the fact that sensors are most practical when they are spread in a multitude numbers, especially for collecting environmental map of a geographical area such as a rain forest, a complete building, or an agriculture field.

Once the sensors are spread in a sensor application, exact position information is of vital importance [1]. The position of the nodes has a significant role in many fields as routeing, surveillance and monitoring, military, environmental and health applications etc. Localization of a sensor node is fulfilled with the aid of neighboring nodes. The localization can be categorized as known location based localization, proximity based localization, angle based localization, range and distance based localization [2].

In this study, we used Time of Arrival Localization (ToA) method which is one of range and distance based localization techniques. The distance between the two nodes is estimated by measuring the duration of propagation of the signal between the two nodes. This requires clock synchronized nodes, utilizing the well-known parameters such as the speed of the signal and the carrier frequency is known as the ToA technique. In previous studies, this technique was used several studies. In [3], each sensor node exploits at least one orthogonal sub-carrier as its assigned marker, to reply the Neighbor Discovery (ND) and ToA estimation requests transmitted by target nodes. The target node utilises the orthogonality throughout sub-carriers to detect the transmitted markers and their corresponding delays [3]. A signal-circle analogy used by Barbeau et al. [4], is generally used analogous to the TOA distance measurement technique.

In literature, statistical analysis related to both localization and energy problem in wireless sensor networks are available in many studies. Kamyabpour et al. [5] use statistical tools to analysis dependency between Wireless Sensor Network (WSN) parameters and overall energy consumption. In this study, three statistical approaches (linear and non-linear correlation, p-value) are implemented to the consequence of detecting phase to extract the most efficacious parameters on WSN comprehensive energy consumption. The distribution of range estimation error is analyzed by Rasool et. al [6] using both graphical and computational goodness of-fit techniques, that are, empirical cumulative distribution function plotting, quantile–quantile plotting, probability density function plotting, kurtosis (K) test, skewness (S) test, linear correlation coefficient (γ) test, Anderson–Darling (A²) test and chi-squared (χ²) test. They proposed range inflation algorithm (RFA) which is based on A² test and it filters out the range estimations with high errors. In [7], equipped with moments, the optimal fusion rule (OFR) distribution is approximated by a Gaussian and Gamma distributions via moment mapping method. They showed that the Gamma distribution fits the OFR distribution to high extent when compared with Gaussian distribution. Tae Hong et al. [8] propose a new data filtering schema based on statistical data analysis. Through performance analysis, they show that the proposed schema does better from the Kalman filtering schema in terms of the number of messages transmission. In [9], the authors present the SA-TC algorithm for detecting and thus defending against this serious threat. It is based on the on-demand multi-path routings and uses statistical analysis and time constraint to identify the suspected links. Tsai et al. [10] report different aspects of a statistical analysis of four representative in-car wireless channels based on the received power data collected.
from a Binary Phase Shift Keying (BPSK) transmission experiment. They used Rayleigh, Log normal, Nakagami, Rice, and Weibull distributions in their study.

In our previous study, we used uniformly distributed network to localize the target nodes while Modified 3N algorithm is being run. But in this paper, we used Normal, Beta, Weibull and Generalized Pareto distributed networks for localization and the localization performance of the networks are evaluated and compared using MATLAB simulations.

II. TIME OF ARRIVAL BASED LOCALIZATION

Time of Arrival (TOA) is a method used to estimate the location of a target node based on the correlation of the signals. This method calculates the distances from each anchor to the target by multiplying the speed of the signal and the time at which the signal is received. This method requires the knowledge of the precise starting time of the signal transmitted, and the precise maintenance and synchronization of the clocks at the target and all the anchor nodes is involved.

In general, the field of sensor nodes is sparse in the sense that some nodes may have fewer than neighboring anchors to fully localize. In fact, they may have less than 3 neighbors. A well-known 3 Neighbor algorithm is as follows: Each node that is not equipped with a position-awareness device sends a position request message, a node that knows or can compute its position sends to it all its neighbors, and a node that
device sends it to all its neighbors, and a node that receives position messages from three different nodes, say A1, A2, and A3, can calculate its position as shown in Fig. 1 (a). However, this algorithm exhibits a deficiency: where a target node receives only two anchor nodes (A1, A2), locations, and two distance measurements, the target node fails to find its own location, due to the obvious ambiguity as shown in Fig. 1(b) [4].

![Fig. 1](image_url)

**A. Modified 3N Algorithm in 2D**

The following modification to the 3N algorithm is proposed in [13]. While the algorithm is being run, the target nodes that are localized are now position-aware and possess the capability to share their positions. This newly found position-aware node is introduced into the pseudo anchor list and the neighboring network is intimated of this change, and the gradual increase of the position-aware nodes in the network enable an enhanced localization performance.

<table>
<thead>
<tr>
<th>Algorithm 1: Modified 3N Algorithm in 2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. While there are target nodes</td>
</tr>
<tr>
<td>a. if maximum number of iterations is exceeded, stop (some targets are not located)</td>
</tr>
<tr>
<td>b. if less than three anchor nodes are in range, skip this node and goto step 1 to consider another target node</td>
</tr>
<tr>
<td>c. if there are three or more anchor nodes in range, find the closest three anchor nodes and use them to locate the target node</td>
</tr>
<tr>
<td>d. Add the localized target node into the pseudo-anchor list and remove it from target list</td>
</tr>
<tr>
<td>2. goto step 1, consider the next in target list</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>III. ANALYSIS OF TIME OF ARRIVAL SIMULATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Design of Simulation Environment</td>
</tr>
<tr>
<td>The simulation environment is designed for the quantitative performance study of the proposed modified 3N Neighbor algorithm in 2D. For simplicity and ease of presentation we limit the environment to 2 dimensions, but the Modified 3N algorithm is capable of operating in 3D. A heterogeneous node network containing a mix of anchor nodes that have the capabilities of ascertaining their own locations and the target nodes that are non-position-aware is generated as shown in Fig. 2. Blue circle nodes and red square nodes represent position-aware and non-position-aware nodes, respectively. A pseudo-anchor list is created that serves as a dynamic anchor list while the simulation is being run. As the new target nodes are localized, they are added to the list of pseudo-anchors, and the whole network is made aware of these newly localized nodes for the purpose of enhancing the performance of localizing other target nodes with the help of this new knowledge. The simulation creates a distance matrix that is generated using the Euclidean method of calculation of the distance between the anchor nodes. The connectivity of the nodes in the network (i.e., the average number of neighbors) is an important parameter that has a strong impact on the accuracy of most localization algorithms. This forms the basis for the generation of other modules needed, such as adjacency lists. This list of the nodes is in the communication range of that particular target node. From this adjacency list, each target node determines its neighbors. An approximated sphere is constructed, using the distance from the anchor node to the target node as the radius and the absolute position of the anchor as the center. The intersection of spheres gives a location estimate of the target node.</td>
</tr>
<tr>
<td>B. Simulation Results for 2D</td>
</tr>
</tbody>
</table>
| In this section, the localization capability of the TOA based localization algorithm is presented with exhaustive Monte-Carlo simulations, and the effect of the input parameters determining the self-localization environment for Modified 3N algorithm in 2D is also presented. The simulation environment to test the performance of the algorithm on all combinations of the context parameters is formulated. Each Monte-Carlo simulation is generated for a particular set of
input parameters and run 100 times with different fields and with randomly located nodes. The results are then averaged. The input parameters include the percentage of anchor nodes (position-aware and initially synchronized nodes), the number of target nodes, and the range of communication, as shown in Fig. 2. With the number of nodes varying from 50 to 400, the percentage of available nodes is localized in a square field dimension of 100x100 units. In some application scenarios, nodes may be mobile. In this paper, however, we focus on static networks, where nodes do not move, since this is already a challenging condition for distributed localization. Fig. 2 shows Normal distribution of 100 nodes with the range of 20 units.

Fig. 3 shows Pareto distribution of 100 nodes. Three parameters of Pareto function, tail index (shape, K), scale parameter sigma and threshold (location) parameter theta, are chosen as 0.1, 0.1 and 1 respectively. When K > 0 and theta is equal to sigma/K, the Generalized Pareto is equivalent to the Pareto distribution.

Fig. 4 shows Weibull distribution of 100 nodes. This distribution has two parameters which k > 0 is the shape parameter and \( \lambda > 0 \) is the scale parameter of the distribution. k and \( \lambda \) are chosen as 1 and 0.12 respectively for this simulation. Fig. 5 shows Beta distribution of 100 nodes. Two parameters of Beta function, \( \alpha \) and \( \beta \), are chosen as 4 and 2 respectively. Asymmetric distributions are obtained by choosing alpha and beta to be different.

Fig. 6 is produced by varying the percentage of anchor nodes from 10% to 35% for a constant communication range of 10% of the field dimension for normal distribution. X-axis is the number of nodes and y-axis is the percentage of target nodes localized. Modified 3N algorithm is run on Pareto, Weibull and Beta distributed environments as shown in Fig 7, Fig. 8 and Fig 9 respectively. The results show that Normal distributed environment is quite sensitive to the change of node numbers. Increasing number of anchor nodes does not change significantly on Weibull, Perato and Beta distributed environments. Among all distributions, Pareto distribution shows the best results.
IV. CONCLUSIONS

Two-dimensional localization in wireless sensor networks have been widely studied in literature. In this paper, the Modified 3N algorithm in 2D is introduced and this algorithm was tested on an environment created with Normal, Weibull, Pareto and Beta distributions.

For all environments, the simulations conducted have shown that the introduction of the knowledge of newly localized nodes into the network enhances its localization capability. If the nodes cannot be located by the 3N algorithm because of the limitations on range and sparsity of the anchors, then those nodes will not be localized by the modified algorithm either. The sensors that detect the movements of the objects are not considered in this paper. They will be addressed in our future work.
REFERENCES


Robust Variable Structure Controllers for Axial Active Magnetic Bearing

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Abstract— This work focuses on robust variable structure control of a rotor-axial active magnetic bearing system. The electromagnetic force generated by active magnetic bearing is highly nonlinear characteristics. On the other hand, the magnetic force coefficient is a calculated value and its real value is not truly identified, therefore, robustness is a great importance in the operation of the active magnetic bearings systems. On this works Lyapunov based three different type of variable structure controllers are proposed and experimentally tested. Robustness of the controllers were tested experimentally by creating some parametric uncertainty in the control system using an external disk mass attached to the rotor. The results of the controllers are also compared with conventional and linear robust controllers.

Keywords— Axial active magnetic bearings, sliding mode controller, high gain robust controller, high frequency robust controller

I. INTRODUCTION

Active magnetic bearings (AMB) are electromechanical devices that provide noncontact support between rotor and bearing via the control of electromagnetic forces. Magnetically levitated rotors have many useful advantages like frictionless rotation. Owing to this, active magnetic bearings allow rotors to reach high rotational speeds [1-2]. However due to the nature of magnetic field, magnetically levitated rotor systems are highly nonlinear and AMBs are represented by nonlinear mathematical models [3-4]. Nevertheless they can be linearized successfully around the operating point thanks to the restricted and very small air gap between AMB stator and rotor [5]. As a result, many linear and local controllers like PID or fuzzy logic controllers [6-7] have been successfully applied to AMB systems. These controllers can offer good performance around the operating point but outside these local regions where the effects of the nonlinearities become more evident. Model based controllers are developed to increase the performance of the AMB system. Due to the magnetic saturation and existence of eddy current effects identification of exact system parameter in a magnetic bearing system is not straightforward. Therefore, robustness is a great importance for this type systems. There are available works on magnetic bearing system using robust control and linear matrix inequality design for controlling the motion of a magnetic bearing system [8-9]. Linear robust control and nonlinear adaptive backstepping control approaches have been studied by many researchers to maintain robustness in magnetic bearing systems [10-12]. Variable structure control theory has been implemented for many nonlinear processes including magnetic bearings [13-15]. One of the main features of this approach is needs to drive the error to a switching surface after which the system is in sliding mode and will not be effected by and modelling uncertainties or disturbances. However, there are two main criticisms of these controllers when they are applied to mechanical systems, first ignoring the dynamics or physical properties of the mechanical system the controllers can do no better than other controllers that disregards the dynamics. Secondly, chattering is a common problem associated with the variable structure controllers.

The remaining of the work is organized as follows: The mathematical model of an axial magnetic bearing system is given in Section 2, while the control problem formulation and error system development are stated in the control design section. Respectively the sliding mode control (SMC), high gain robust control (HGR) and high frequency robust control (HFR) are designed and experimental results are given in the rest of the paper.

II. AXIAL MAGNETIC BEARING MODEL

The axial active magnetic bearing produces attractive magnetic forces by the opposite coil electromagnets to limit the rotor movements in z direction. The structure of axial bearing in xOz plane is depicted in Fig. 1 schematically. In this structure, a disk element is fixed to the rotor and a nominal gap z₀ exists between the opposite coils and the disk element in both side. A non-contact capacitive sensor is set to measure the axial displacement of the rotor. The aim of the control is to bring the disk element to the origin without any mechanical contact during levitation and rotation of the rotor. The parameters of the considered system are given in Table 1. Note that an external disk is possible to be fixed to the rotor to test the robustness of the controllers.

In this study, it assumed that the radial and the axial directions are completely separated. This means two radial active magnetic bearings support the rotor in the radial directions and during the control operation a complete noncontact situation is realized. As depicted in Figure 1, the magnetic force f₂ is nonlinear in nature and is generated by the coils of bearing in the following form.

\[ f_2 = f_r - f_0 = k \left( \frac{(z_0 - z)^2}{(z_0 - z)^2 - (z_0 - z_i)^2} \right) \] (1)
where $k$ is a constant related to the magnetic bearing parameters. To derive the dynamical equation of the proposed system a linearized magnetic force is assumed to have the following form.

$$m\ddot{z} = k_xz + k_i\dot{z}$$  \hspace{1cm} (2)

where $z(t), \dot{z}(t) \in \mathbb{R}$ represent the rotor position and acceleration, respectively. Also, $i_s(t) \in \mathbb{R}$ denote the control current signal. Besides $m \in \mathbb{R}$ is the mass of the rotor, $k_x \in \mathbb{R}$ and $k_i \in \mathbb{R}$ are the constants according to displacement to force constant $k_x = 4k(i_0^2/z_0^2)$ and current to force constant $k_i = 4k(i_0/z_0^2)$ where; $k_i = \mu_0N^2A/4$.

![Diagram of axial active magnetic bearing rotor system](image)

Fig. 1 Schematic representation of the axial active magnetic bearing rotor system

To ease the presentation of the subsequent control development, we divide both sides of the dynamics equation by the non–zero constant $k_i$ to obtain:

$$i_x = M\ddot{z} - Cz$$  \hspace{1cm} (3)

where $M \equiv m/k_i$ and $C \equiv k_x/k_i$. The compact form of the equation can be written as

$$i_z = W\phi$$  \hspace{1cm} (4)

where $W = [\ddot{z} - z]$ and $\phi = [M \ C]^T$.

### III. Design of the Controllers

In the considered axial bearing–rotor system, the objective of the control is to force the disk to the middle position with equal gaps in both sides. To this aim, define a position tracking error $e(t) \in \mathbb{R}$ and its double time derivatives, denoted by $\ddot{e}(t) \in \mathbb{R}$, as follows

$$e = z_d - z$$  \hspace{1cm} (5)

where the desired trajectory of the rotor is $z_d = 0$. The filtered tracking error $r(t) \in \mathbb{R}$ and its time derivatives for the analysis, denoted by $\dot{r}(t) \in \mathbb{R}$, as follows

$$r = \dot{e} + \alpha e$$  \hspace{1cm} (6)

$$\dot{r} = \dot{e} + \alpha \ddot{e}$$  \hspace{1cm} (7)

where, $\alpha \in \mathbb{R}$ is a positive control gain. Take time derivative of filtered tracking error and multiplied by $M$ both side of the equation

$$M\dot{r} = M\ddot{e} + M\alpha\ddot{e}$$  \hspace{1cm} (8)

Rearrange (7) by substituting (3), (5) and (6) into it as follows

$$M\dot{r} = M(\ddot{z}_d + \alpha \dot{e}) - C\dot{z} - i_z$$  \hspace{1cm} (9)

Design the obtained controller:

$$i_z = \bar{W}(t) + k_x r + k_i \int r dr + V_R$$  \hspace{1cm} (10)

where $\bar{W}$ is the best estimates function of the system parameters. The selection of $V_R$ defines the type of the controller. Note that the integral term is not consist on the variable structures controllers. However, experimental results have shown that the steady-state error occurs when levitating the rotor. Therefore, substituting the integral effect on control signal equation (10) more reliable results are obtained. The aim of this study is to apply variable structure control in the selection of $V_R$ to have better robustness in the control system.

### A. Sliding mode controller (SMC) design

Using equation (10), the first type controller input is defined as

$$i_{z_{-SMC}} = \bar{W}(t) + k_{x_s}r + k_{is} \int r dr + \rho_s \text{sgn}(r)$$  \hspace{1cm} (11)

For the stability analysis, a candidate Lyapunov function (12) and its derivative (13) are defined as

$$V = \frac{1}{2}M\dot{r}^2 + \frac{1}{2}k_{is}\xi^2$$  \hspace{1cm} (12)

$$\dot{V} = M\dot{r}\dot{r} + k_{is}\dot{\xi}\dot{\xi}$$  \hspace{1cm} (13)

### Parameters of axial magnetic bearings system

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Symbols</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of the rotor</td>
<td>$m$</td>
<td>4.821</td>
<td>[mm]</td>
</tr>
<tr>
<td>Mass of the external disk element</td>
<td>$m_d$</td>
<td>0.383</td>
<td>[kg]</td>
</tr>
<tr>
<td>Nominal gap</td>
<td>$z_0$</td>
<td>0.25</td>
<td>[mm]</td>
</tr>
<tr>
<td>Bias current</td>
<td>$i_0$</td>
<td>2.5</td>
<td>[A]</td>
</tr>
<tr>
<td>Number of turns in the electromagnets</td>
<td>$N$</td>
<td>24</td>
<td>[-]</td>
</tr>
<tr>
<td>Surface area of the electromagnets</td>
<td>$A$</td>
<td>419</td>
<td>[mm$^2$]</td>
</tr>
<tr>
<td>Magnetic permeability constant</td>
<td>$\mu_0$</td>
<td>$4\pi 10^{-7}$</td>
<td>[H/m]</td>
</tr>
</tbody>
</table>
where $\xi = \int r dr$ and the derivative of $\dot{\xi} = r$. The final form of derivative of $V$ is obtained by inserting equation (9) and (11) into the closed equation (13)

$$\dot{V} = M \dot{r} + k_{is} \ddot{\dot{r}} = (w(t) - \ddot{\omega}(t) - k_r \ddot{r} - \rho_s \sigma \dot{r} - k_{ig} \dot{\dot{r}}) r + k_{is} \ddot{r}$$

Since $\sigma(r) = (|r|/r)$, and $\ddot{\omega}(t) = w(t) - \ddot{\omega}(t)$ the equation (14) becomes;

$$\dot{V} \leq \ddot{\omega}(t) r - k_r \ddot{r}^2 - \rho_s |r|$$

Assume that there exists a $\rho_s(t) \in \mathbb{R}$ such that $\rho_s(t) \geq ||\ddot{\omega}(t)||$. The following upper bound can be formed;

$$\dot{V} \leq k_r \ddot{r}^2$$

Finally, the derivative of $V$ becomes

$$V > 0 \Rightarrow V \in L_{\infty} \Rightarrow \lim_{t \to \infty} V = V_{\infty}$$

It is clear that a global stability is maintained and all signals in the closed system are bounded.

**B. High gain robust (HGR) controller design**

The second type controller input is high gain robust controller defined as

$$i_{x-HGR} = \ddot{\omega}(t) + k_r \ddot{r} + k_{ig} \int r dr + \frac{\rho_s^2}{\epsilon} r$$

where $\epsilon > 0$ is a positive constant. For the stability analysis, the Lyapunov function given in equation (13) is used by replacing with the parameter $k_{ig}$. The derivative of $V$ is obtained as by inserting equation (9) and (18) in to the closed equation (13)

$$\dot{V} = \left( w(t) - \ddot{\omega}(t) - k_r \ddot{r} - \frac{\rho_s^2}{\epsilon} r - k_{ig} \dot{\dot{r}} \right) r + k_{ig} \ddot{r}$$

Assume that there exists a $\rho_s(t) \in \mathbb{R}$ such that $\rho_s(t) \geq ||\ddot{\omega}(t)||$. And in equation (19) replace $\dot{\ddot{\omega}}(t)$ with $\ddot{\omega}(t)$ and the following upper bound can be formed;

$$\dot{V} \leq -k_r \ddot{r}^2 + \rho_s |r| - \frac{\rho_s^2}{\epsilon} r$$

Rearranging equation (20);

$$\dot{V} \leq -k_r \ddot{r}^2 + \rho_s |r|\left(1 - \frac{\rho_s |r|}{\epsilon}\right)$$

**Case-1:**

$$\rho_s |r| > \epsilon \Rightarrow 1 - \frac{\rho_s |r|}{\epsilon} < 0$$

**Case-2:**

$$\rho_s |r| \leq \epsilon \Rightarrow 1 - \frac{\rho_s |r|}{\epsilon} \geq 0$$

Under these cases the derivative of the candidate Lyapunov function is transformed into the two different types:

**From case-1:**

$$\dot{V} \leq -k_r \ddot{r}^2$$

**From case-2:**

$$\dot{V} \leq -k_r \ddot{r}^2 + \epsilon$$

The worst case between case-1 and case-2, the derivative of the candidate Lyapunov function with the following upper bound can be formed;

$$\dot{V} \leq -k_r \ddot{r}^2 + \epsilon$$

therefore global ultimately upper bound stability is satisfied.

**C. High frequency robust (HFR) controller design**

The third type controller input is proposed as

$$i_{x-HFR} = \ddot{\omega}(t) + k_r \ddot{r} + k_{if} \int r dr + \frac{\rho_f^2}{\epsilon} r$$

Using the same candidate Lyapunov function for the stability analysis, the derivative of $V$ is obtained by substituting equation (9) and (25) to the equation (13)

$$\dot{V} = \left( w(t) - \ddot{\omega}(t) - k_r \ddot{r} - \frac{\rho_f^2}{\epsilon} r/|r| + \epsilon \right)$$

$$- k_{if} \dot{\dot{r}} r + k_{if} \dot{r} \dot{\dot{r}}$$

Assume that there exists a $\rho_f(t) \in \mathbb{R}$ such that $\rho_f(t) \geq ||\ddot{\omega}(t)||$. And in equation (26), replace the $\ddot{\omega}(t)$ with $\ddot{\omega}(t)$ and the following upper bound can be formed;

$$\dot{V} \leq -k_r \ddot{r}^2 + \rho_f |r|\left(1 - \frac{\rho_f |r|}{r|/| + \epsilon}\right)$$

Rearrange the equation and the following upper bound can be formed;

$$\dot{V} \leq -k_r \ddot{r}^2 + \rho_f |r|\left(\frac{\epsilon}{r|/| + \epsilon}\right)$$

where $\rho_f |r| \leq 1$; the derivative of $V$ becomes

$$\dot{V} \leq -k_r \ddot{r}^2 + \epsilon$$

therefore global ultimately upper bound stability is satisfied.

**IV. EXPERIMENTAL VERIFICATIONS**

The flexible rotor-active magnetic bearing experimental setup used in the control design study is shown in Figure 2. The experimental setup is a five axis controlled rotor-active magnetic bearing system and the radial and the axial bearings can be controlled separately. The axial magnetic bearing is located at the one end of the rotor and limits the rotor axial
movements. The air gap $z_0$ between the rotor and the touchdown bearing is set to 0.15 [mm].

In experiments, the controller implementations and the data acquisitions were performed using dSPACE DS1104 system. The working sample rate was selected as $T_s = 15 \text{ kHz}$ in all experiments. The best estimates of the system parameters were taken as $\varphi = [M \ C]^T = [10000 \ 0.3974]^T$. In experimental verifications, two cases were studied to understand the performance and robustness of the designed robust variable structure controllers. In the first case, experiments were carried out with the own weight of the rotor in the system. For the second case, an external disk mass was mounted at the end of the rotor as shown in Figure 3. After adding the disk mass, the total mass of the rotor became 5.204 [kg] and the increase in the rotor mass was about 8% percent. Adding an extra mass on the rotor imposes some parametric uncertainty to the control system and also some dynamic unbalance forces in the rotation of the rotor even in the axial direction due to imbalances in the external disk.

**A. Experimental Results of Variable Structure Controllers**

The variable structure controllers were tested at the rotor speed of 3000 rpm for two cases and the displacement of the rotor and the control input were observed for each cases of with and without disk. The results obtained with the sliding mode controller are shown in Fig. 4. As shown in these figures, small increases were observed in the amplitude of displacement and the control input when the external disk attached to the rotor. The parameters of sliding mode controller for both case were selected as $\alpha_s = 10, k_{rs} = 1000, \rho_s = 0.1$ and $k_{is} = 450$.

![Fig. 4 Sliding mode control results, (a) displacements, (b) control inputs](image)

The second results were obtained for the high gain robust controller as shown in Fig. 5. For this controller, the parameters were selected as $\alpha_g = 20, k_{rg} = 900, \rho_g = 0.0001, \varepsilon_g =$

![Fig. 5 High gain robust control results, (a) displacements, (b) control inputs](image)
0.000001 and $k_{ig} = 600$. Although increase in the amplitudes of responses with external mass were reasonable, some phase shifts were observed in the displacements and control inputs.

The high frequency robust control results were presented in Figure 6. In this controller, the parameters were $a_f = 25$, $k_{rf} = 1000$, $\rho_f = 0.001$, $\epsilon_f = 0.000001$ and $k_{if} = 500$. Much better results were obtained in displacements and control inputs compared to other variable structure controllers as shown in Figure 6.

![Figure 6](image)

**Fig. 6** High frequency robust control results (a) displacements, (b) control inputs

**B. Comparison of Experimental Results**

The results of variable structure controllers were compared with the results of conventional PID control and linear $H_\infty$ robust controller. These controllers were tested before for the same rotor magnetic bearing system [16] and were believed to have good performances. For the same test conditions and rotational speed of the rotor, the results obtained for PID control are shown in Figure 7. The robustness of PID control is weak against the parameter variation. The results of linear $H_\infty$ controller were presented in Figure 8. Since $H_\infty$ controller was designed by considering some uncertainty models, small increases in the amplitude of the rotor were observed with the disk mass.

The experimental results of the all tested controllers with external disk mass were presented in Fig.9 and without disk given in Fig.10. Also Table 2 shows RMS values of obtained experimental data. It can be detected that high frequency robust controller gives best results either in the amplitude of the rotor and the control inputs. The other two variable structure controllers have also reasonable results. The results of linear $H_\infty$ control shows the conservativeness of the controller with large control input values but almost no increase in the amplitude of displacements but some phase shifts were observed in the displacements and control inputs.

![Figure 7](image)

**Fig. 7** PID control results (a) displacements, (b) control inputs

![Figure 8](image)

**Fig. 8** $H_\infty$ control results, (a) displacements, (b) control inputs

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>RMS VALUES FOR ALL EXPERIMENTAL DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PID</td>
</tr>
<tr>
<td>Without disk</td>
<td></td>
</tr>
<tr>
<td>Displacement</td>
<td>0.0061</td>
</tr>
<tr>
<td>Control input</td>
<td>1.1023</td>
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<tr>
<td>With disk</td>
<td></td>
</tr>
<tr>
<td>Displacement</td>
<td>0.0089</td>
</tr>
<tr>
<td>Control input</td>
<td>1.2426</td>
</tr>
</tbody>
</table>
Fig. 9 All tested controller results with external disk mass, (a) displacements, (b) control inputs.

Fig. 10 All tested controller results without external disk mass, (a) displacements, (b) control inputs.

V. CONCLUSIONS

In this paper, three type of robust variable structure controllers have been designed and tested experimentally for a rotor-axial active magnetic bearing system. Robustness of the controllers were tested experimentally by creating some parametric uncertainty in the control system using an external disk mass attached to the rotor. RMS values from the obtained data of the displacements and the control inputs have shown a good comparison of the controllers. The high frequency robust controller results have shown much better performance in all tested controllers.

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REFERENCES

IMPLEMENTATION OF FUZZY LOGIC BASED SPEED CONTROL OF BRUSHLESS DIRECT CURRENT MOTORS VIA INDUSTRIAL PC

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Abstract— The brushless direct current motors are often preferred in the industry due to their high development torques, efficiencies, speed and position controls. Especially, they are used with robotic, numeric-controlled machines, electrical vehicles, etc. One of the biggest difficulties of these motors is the closed loop operation of these motors with driver circuits and a controller. In this study, the speed control of the brushless direct current motors was made with PLC-based industrial computer by using the methods of PID and Fuzzy Logic. PLC based industrial computer of Beckhoff firm CX9020 was preferred as a controller. In this industrial computer, the software of the controller was developed by using Structured Text programming language of TwinCat 2.11 program. In experimental studies, the speed control of the brushless direct current motors is made with PID and fuzzy logic controller, according to the requested reference. The performances of the controllers were tested by using step, ramp and ladder functions. While PID controller gave better results in reference speed areas whose parameters were determined, fuzzy logic controller gave better results in variable references. Although PID is given as a ready block in PLC and PLC based controllers, fuzzy logic is under development in many of them. In this study, classical PLCs and PLC based industrial PCs, which did not have any fuzzy logic controller module, were transformed into intelligent controllers with Structured Text programming language. As a result of this, classical PLCs and PLC based industrial PCs can be used in intelligent control, which is very important for industry 4.0.

Keywords— fuzzy logic, speed control, industrial pc

I. INTRODUCTION

The brushless direct current motors (BLDC Motors) are electric machines used widely on applications requiring high efficiency and strength. They are used in many areas, especially in automotive and aviation industries, as an actuator [1]. The brushless direct current motors are often preferred for special implementations in the industry, compared to brushed direct current motors and asynchronous motors, due to their features such as speed-torque characteristics, high-dynamic-responses and high efficiencies [2]. Strength is very important for motors being used in automotive and aviation industries. They are preferred for almost every implementation in the industry because decay probability of brushes of brushed direct current motors under dynamic forces is high and efficiency and performance of asynchronous motors are low [3].

Speed control of a brushless direct current motor can be made by using the pulse width modulation (PWM) [4]. Requested input/output operations are widely used in the industry by using programmable logic controllers (PLC), and they are also used for motor speed control applications requiring high precision and accuracy [5]. For speed control of brushless DC motors, fuzzy logic controller can be used by integrating it in PID controller software [4,5]. Additionally, speed controls of brushless and brushed DC motors can be modeled on Matlab/Simulink platforms without any applications, and speed controls can be made by using a fuzzy logic controller [6]. At the present time, it is known that they are being used in electric vehicle technologies by making speed controls on permanent-magnet (PM) in-wheel electric motors [7].

Industrial PCs are the general name of Intel x86-based computer platforms manufactured for industrial purposes as in the definition. As an example for other platforms, PLCs, micro-controllers and DSP-based processors can be given. Main features which differ industrial PCs from commercial PCs are their high security, endurance under difficult conditions and suitability for long-term uses [8].

Industrial PC manufacturers in the World are Advantech, Allied Electronics, Aplex Technology, AutomationDirect, B&R Industrial Automation and Beckhoff Automation. In this study, speed control of a brushless direct current motor has been made in an experimental setup designed and prepared for the study conducted, by using fuzzy logic controller and PID controller on an industrial computer. On the industrial computer, fuzzy logic controlled has been executed in “Structured Text” programming language as software, and the performance of the software developed via smart controllers that are available to use in Industry 4.0 of which name is mentioned most often in recent years have been tested with experimental works thanks to the study.
II. MATERIALS AND METHOD

A. Preparing the Experimental Setup

Brushless direct current motors are hard-to-control applications. Relaying power components in motor driver circuits and reading the speed data on the encoder require speed and computational time. For testing these softwares developed because of these reasons, this problem has been preferred. Brushless direct current motors are used in robotics, numeric controls (NC), computer numeric controls (CNC) and precise implementations. Areas of usage are rapidly increasing. In the study, PID and fuzzy logic control has been chosen on speed control for the brushless direct current motor brand Oriental type BLH230KC-30 by using Beckhoff CX9020 industrial computer. The experimental setup has been designed and prepared in order to perform this implementation. 2 “two” motors have been used in the experimental setup, and they have been loaded with fixed load by connecting wheels to motor shafts with direct-connection and 2 “two” drums have been attached under them with a tangential-connection for the purpose of force application to the wheels. With the fixed load implemented, the motor is caused to consume 0.64 A(Ampere) current. Revs per minute during the motor run time has been read by encoders being used in the system, speed measurement has been performed via Beckhoff CX9020. With the thermocouple type “K” connected in between motors, mean temperature of the motors is determined, and the system is halted in case of the potential temperature increasing and high velocities being reached. The visual of the block diagram belonging to the study and the visual belonging to the experimental setup prepared have been given, respectively, on Fig. 1 and Fig. 2.

---

![Fig. 1 Block Diagram of the Study](image1)

![Fig. 2 Experimental Setup Prepared](image2)
B. Industrial PCs
Utilized in the study, CX9020 industrial PC of BECKHOFF automation firm is an Ethernet control system mounted on DIN rail, integrated with 1 GHz ARM Cortex™-A8 CPU. Connection for Beckhoff I/O systems has directly been integrated into CPU module. CX9020 consists of two microSD card slots, internal ram as nonvolatile memory, 128 kB NOVRAM and CPU. It externally contains two Ethernet RJ45 interfaces, four USB-2.0 interfaces and DVI-D interface. Operating system Microsoft Windows 7 CE can be run with TwinCAT 2.11 interface software without visuals or visualization [9].

C. Brushless Direct Current Motor
BLH230 series BLDC motors manufactured by Oriental brand are one type of motors manufactured by the firm that can work with high precision. For the control of the motor, a motor driver is provided, as well, for the user by the firm. In this way, the motor control can be made more easily and with more precision. By means of the sensors integrated on motor driver card, damages to the system are prevented with motor power-off system activating when there is over current, over heat and over strain [10]. There is a speed-torque graph given belonging to BLH230KC-100 brushless direct current motor in the Fig. 4, and pictures belonging to the motor and motor driver in the Fig. 5. According to Fig 4, take-off torque of the motor is 0.15 Nm and nominal torque is 0.12 Nm. 2500 rpm/min is the threshold value of the nominal torque provided by the motor. When the motor reaches to the maximum speed, the torque value is half of the nominal running torque (0.6 Nm). Suggested work area of the motor is between 0.12-0.15 Nm torque range and 100-2500 rpm/min revolution range.

D. Pid control system in use in the experimental setup prepared
PID control method is widely used in process control in industrial applications. Control systems engineers prefer PID controller because of its flexibility and reliability. The transfer function of a PID controller including proportional, integral and derivative terms are given in (1).

\[ K(s) = K_p + \frac{K_i}{s} + K_ds \]  

In equation (1), \( K_p \) is proportional gain, \( K_i \) is integral gain and \( K_d \) is derivative gain. By tuning coefficients of PID controller, it provides control for specific process requirements. The proportional term produces an output value that is proportional to the current error value. This proportional term is related to current state of process variable. The integral term is proportional to both the magnitude of the error and the duration of the error. When integral term is added to proportional term it accelerates the movement of the process towards setpoint and eliminates the residual steady-state error that occurs with a pure proportional controller. The rate of change of process error is calculated by determining the slope of the error over time. The rate of change is multiplied by derivative gain [11]. In equation (2), the error which is the input parameter of PID controller is calculated by the difference between measured value \((r(t))\) and the output of PID controller \((y(t))\). In equation (3), the output function of PID controller is given.

\[
ed(t) = r(t) - y(t) \]  
\[
y(t) = K_p e(t) + K_i \int_0^t e(t) dt + K_d \frac{de(t)}{dt} \]  

E. Fuzzy Logic Control
Fuzzy Logic is a logical structure that has come in sight as a result of an article published by Lotfi Zadeh in 1961. The fuzzy logic is based on fuzzy-set and sub-sets. When it is stated mathematically, the value of the entity is set as “1” when it is an element of the set, and set as “0” when it is not an element of the set, in terms of its relationship with the set. Fuzzy logic is an extension of classical set notation. In a fuzzy set, each entity has a membership degree. Membership degree of entities can have any value between (0,1) range and membership function is shown with \( M(x) \) [12]. In fuzzy logic deduction, linguistic varieties can be formed as membership functions of triangle type, trapezium type and cauchy type [13]. In the study, variables have been generated based on triangle type membership functions. Triangle membership function is given on Equation 4.
A \mu (x) \begin{cases} 0, & x < a_1 \\ \frac{x - a_1}{a_1 - a_2}, & a_1 \leq x \leq a_2 \\ \frac{a_3 - x}{a_3 - a_2}, & a_2 \leq x \leq a_3 \\ 1, & x > a_3. \end{cases} \tag{4}

Here \( \alpha_2 \) can be defined as a fixed value. Fuzzy logic presumes, depending on \( \alpha \) coefficient, that values close to \( \alpha_2 \) would be represented with the meaning assigned to this value. In other words, uncertainty in \( \alpha_2 \) can be reduced to minimum values with a \( \alpha \) coefficient that will be presumed or can be found based on the distribution.

In this study, engine rpm has been chosen as the process variable. System input variables have been defined as the revolution fault \( e \) between reference motor rpm and current motor rpm, and the change in revolution fault \( ce \). As system output variable, cycle change of the analog output signal sent to the driver circuit making the speed control of the motor.

\[ e(i) = ref(i) - (i) \]
\[ ce(i) = e(i) - e(i-1) \]

Here \( ref(i) \) is the reference number of revolutions required during the \( i \)th sampling, \( (i) \) is the present number of revolutions of the motor during the \( i \)th sampling, \( e(i) \) is the revolution fault during the \( i \)th sampling, and \( ce(i) \) is the change in revolution fault during the \( i \)th sampling.

The fault, the change in the fault and control variables are placed in the universal set. After the measurement of the system variables, input data measured is turned into suitable linguistic variables in a way that they would be labels of fuzzy sets. These linguistic variables are; PH: (Positive High), PM: (Positive Medium), N: (Null), NM: (Negative Medium), NH: (Negative High). A fuzzy set is defined by assigning a degree of membership value for each elements in the universal set. There are many types of membership function. Preference of those membership functions is up to the user.[14] Since this implementation requires a simpler calculation, triangle type membership functions have been preferred.

For the speed control of the motor, the fuzzy logic controller has been designed first, and fault, change in fault and variable data fuzzification has been made. After the fuzzificated data has been processed in rule basis, they have been defuzzificated and acquired as analog output data. Visuals belonging to fuzzificated membership functions of input and output variables of fuzzy logic controller and belonging to sample software codes developed via “Structured Text” language on Twincat program which is the industrial PC control interface are given on Fig. 6, Fig. 7, Fig. 8, Fig. 9, Fig. 10 and Fig. 11.

After the fuzzification of input and output data, rule base has been designed. While generating the rule base, responses of the motor has been considered and tested by interpreting expertly. On the Matlab/Fuzzy Logic Toolbox platform, a fuzzy logic controller sample has been designed and the controller output has been simulated on the said platform. The rule base is extremely important for implementing the requested output value by comparing the data of fault and changes in fault. Linguistic expression of the rule base in the Fig. 12, visual graph acquired from Matlab/Fuzzy Logic Toolbox platform in the Fig. 13 and part of the software developed belonging to rule base has been given in the Fig. 14.
After the necessary designs have been made for fuzzy logic control, software codes have been written on Twincat interface in order to execute the application. The study has been performed after all processes were completed, controls of the motors have been performed. Revolution data and heat data obtained from the motors have been processed with the controller, and the study has been completed according to the program developed. Additionally, with touch panel of Beckhoff CP6907, all variable information is displayed on the panel with an integrated study. On the panel, information of motor revolutions, heat and analog output value given by the controller has been shown. Screen image of the study has been given on Fig. 15.

III. EXPERIMENTAL STUDIES

During the experimental study, PID control has been compared with the results of fuzzy logic control. As reference to PID and fuzzy logic controllers, step, ladder and ramp functions have been applied, and the results have been obtained graphically on Twincat 2.11 Scope View software working integrated with Beckhoff. Response of PID and fuzzy logic controllers to the ladder function reference has been given in the Fig. 16.
In response to step function in the Fig. (16.a), motor revolution is reaching to the requested step value softer and steadier compared to the Fig. (16.b). It is seen that reference excess is high in the Fig. (16.b) and Fig. (16.d) while reference value is at 2500 rpm/min. In addition, after the reference value requested in the Fig. (16.a) has been reached, it is seen that the presence of oscillation is lesser than the Fig. (16.b) in step response. In the Fig. (16.c) it is seen that the engine revolution is reaching to the requested step value softer and steadier and that the presence of oscillation is lesser compared to the Fig. (16.d) in step response.

The response of the PID and fuzzy logic controllers to ladder type function reference is given in the Fig. 17.

In the ladder response in the Fig. (17.b), revolution of the motor is reaching to the requested reference value faster compared to the Fig. (17.a). However, revolution of the motor is reaching to the requested reference value softer in the Fig. (17.a) compared to the Fig. (17.b). As a reason for this, the cycle speed of the system shows a decrease since the software of fuzzy logic controller is rather heavy. Additionally, while the response of fuzzy logic controller at low revolution reference in responses in the Fig. (17.a) and the Fig. (17.c), there is oscillation in responses in the Fig. (17.b) and the Fig. (17.d). As the reason for the said oscillation, it is seen that process coefficients of PID controller being constant negatively affects the system response in reference values. Since the variables of fuzzy logic controller are defined linguistically, it does not change its response among defined reference values. According to the ladder response, in graphs of the Fig. (17.c) and the Fig. (17.d) acquired without applying load on the motor, it has been seen that the revolution of motor has dropped to the zero based on the oscillation from the rotor of the motor. In reference response in the Fig. (17.c), it is seen that the revolution of motor is reaching to the reference value softer and steadier, and there is seen lesser oscillation compared to the Fig. (17.d). Response of PID and fuzzy logic controllers to ramp type function reference is given in the Fig (3.3).

Fig. 17 Ladder response given by fuzzy logic controller under the load is (a), ladder response given by PID controller under the load is (b), ladder response given by Fuzzy logic controller without load is (c), the response given by PID controller without load is (d).

Fig. 18 Ramp response given by fuzzy logic controller under the load is (a), ramp response given by PID controller under the load is (b), ramp response given by Fuzzy logic controller without load is (c), the ramp response given by PID controller without load is (d).
In reference response in the Fig. (18.a), the revolution of motor is reaching to the requested step value with more oscillation and later steadiness. The reason for this is the slowness of the response of fuzzy logic controller to the rapidly-changing reference. However, although the reference was changing rapidly, while unwanted sawtooth response graph did not occur in the Fig. (18.a), it has been seen in low references in the Fig. (18.b). The reason for this is constant coefficients of P, Ki and Kd within the software of PID controller. In step response in the Fig. (18.c), it is seen that the revolution of motor is reaching to the requested step value softer and steadier, and lesser oscillation is seen compared to the Fig. (18.d).

IV. CONCLUSIONS

In this study, speed control of brushless direct current motor has been made by using fuzzy logic controller via an industrial computer. Responses given by fuzzy logic controller to the requested reference value have been obtained from step, ladder and ramp functions, and they have been compared via PID controller designed for the purpose of monitoring the performance of the responses given by the fuzzy logic controller. According to the results of system responses, although PDI controller runs at certain value ranges more efficiently, it has been seen that the controller efficiency was decreasing as the reference range was increased. However, since the fault variable is determined in the fuzzy logic controller linguistically, it is seen that increasing the value range of the reference does not affect the operation of the controller. Additionally, since the oscillation of the brushless direct current motor was being prevented, it has been seen that its system responses had been more efficient.

Since fuzzy logic controllers contain linguistic variables within, the implemented software generates a huge memory space in the memory of the hardware used. Implementations of fuzzy logic controllers are performed by using high-speed processors or electronic cards in general. As a result of the study, it has been determined that Beckhoff CX9020 industrial computer properly runs the designed fuzzy logic controller of which software was written. Having a major importance in the industry, industrial PCs supporting these sorts of controller structures is seen to be providing comfort and opportunity for applications having Industry 4.0 standards in terms of utility of industrial PCs due to their availability for coding and them being faster than PLCs used in the industry.

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Electrochemical discharge machining: A review

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Abstract—In this study, progress and sort of electrochemical discharge machining (ECDM) that was developed to manufacture the micro features like micro grooves, micro pillar, micro holes and micro channels etc. were investigated. Many materials can be machined regardless of material conductivity, hardness and strength by ECDM using electro chemical machining (ECM) and electric discharge machining (EDM) combination. Researchers developed electrochemical discharge drilling (ECDD), turning (ECDT), grinding (ECDG), milling, dressing, trepanning, wire ECDM, die-sinking ECDM, rotary ECM, powder mixed ECDM, magnetic field assisted ECDM, vibration assisted ECDM methods. Pyrex, glass, stainless steel, cermet, soda lime glass, quartz, silicon nitride, zirconium oxide, borosilicate glass, diamond crystals, e-glass/epoxy composite, kevlar/epoxy composite and silicon wafer were used as a work piece. Effects of machining voltage and drilling depth on mean diameter, influence of tool travel rate on groove width and depth and effects of voltage types on micro holes accuracy and machining type etc were investigated. This review is to discuss the results of studies and applicability of this methods. It sums up also with a vision for future research in electrochemical micromachining.

Keywords—Electro chemical machining (ECM), electric discharge machining (EDM), electrochemical discharge machining (ECDM), micro machining

I. INTRODUCTION

Increase of utilization of micro scale products in wide range of science and technology fields leads researchers to investigate more about these fields. Electrochemical machining (ECM) only for electrically conductive materials, electric discharge machining (EDM) for electrically conductive materials and non-conductive materials only with specific set-up remain incapable of manufacturing of micro scale products. Thus, researchers have been tried to find new hybrid methods to manufacture micro scale products irrespective of material conductivity and strength. Electrochemical discharge machining (ECDM) that is a combination of ECM and EDM was developed by Kurafuji and Suda in 1968[1] but it was first described by physicists Hippolyte Fizeau (1819-1896) and Leon Foucault (1819-1868) [2]. The basic configuration of ECDM was shown in Fig 1[3]. Researchers developed new processes, the same with ECDM essentially, in times. In this study, these new kinds of ECDM processes and investigations to enhance material removal rate (MRR) of ECDM were analyzed.

II. ECDM IN LITERATURE

Before to develop the ECDM, researchers tried to understand the electrochemical discharge phenomenon. One of the first investigations on this is the effect of different power supply configurations and electrolytes in 1993 by Raghuram et al. [4].

Because, the critical voltage was important to determine the material removal rate and enhance MRR. Basak and Ghosh [5] developed a model and compare numerical results with experimental ones to predict the MRR. Besides, Ghosh [6] presented the principle and possibilities of ECDM. Among early works in literature, Bhattacharyya et al. [7] analyzed different process parameters on MRR and they attempted to specify the proper tool shape. Kulkarni et al. [8] were the other researchers to investigate the mechanism of the ECDM process. They paid attention to relation among the time-varying current, temperature rise and MRR. A mathematical model was developed to relate among machining parameters with process criteria by Sarkar et al. [9]. Conclusions showed that applied voltage had more effects on material removal rate, radial overcut and heat affected zone. Chak et al. [10] developed new tools for electrochemical discharge drilling to prevent the decrease on MRR with increasing machining depth. Spring-fed cylindrical hollow brass tool and spring-fed cylindrical abrasive tool were used to drill aluminum oxide (Al₂O₃). Coteate et al. emphasized the effects of some parameters (the voltage, the electrode tool diameter and the work liquid density) on the electrode tool wear [11], the effects of the input parameters on the tool wear and on the drilling speed [12], the effects of the voltage, the capacity of electric circuit on tool wear [13]. Chavoshi and Behagh [14] investigated and discussed the hole length and axial wear parameters and relation between them. That results were cited from the paper by Coteate[13].

Liu et al. [15] developed new wire ECDM process to machine particle-reinforced aluminium alloy 6061 and researched the influences of current, pulse duration and electrolyte concentration on MRR. Results indicated that most effective factor for the highest MRR is the applied current. Again, they [16] developed a grinding-aided model to machine particulate reinforced metal matrix composites (MMCs). This new method enhanced efficiency of machining and surface

Fig. 1 Basic cell configuration in electro-chemical discharge machining [3]
quality on MMCs. Also to predict of critical breakdown voltage they developed a model [17] corresponding with experimental results. Cao et al. [18] machined 3D micro-structures less than 100 µm in size and achieved good surface in spite of minimized structures (Fig 2). It was revealed that high voltage reduced machining resolution. Thus, they reduced required voltage by means of a load cell and the tool electrode with small layer depth.

Cheng et al. [19] investigated the influences of the machining parameters on gas film quality which is very important factor on machining quality. Again, they [20] used new process wire ECDM with electrolyte supplied in titrated flow to fabricate the micro-scale features. The results remarked that this new cost effective and environmental friendly process enable better machining outcomes with less width. Finite element based model for ECDM drilling was developed to predict discharge regime by Wei et al. [21]. Jiang et al. [22] determined spark energy to model spark generation and this finite element model were validated with experiments. They [23] also modelled gas film evolution and validated with experiments to enhance the machining efficiency and quality. The influences of process parameters of ECDM on MRR were researched for borosilicate glass and process parameters were optimized using Taguchi’s method by Paul and Hiremath [24]. Adding surfactant to electrolyte increased the current density and stabilized the current, hence provide better quality [25]. Razfar et al. [26] studied effects of different types of longitudinal oscillation on machining speed and hole depth. Results revealed that although vibration did not effect on the process with micro drill, it was quite effective such as MRR up to 40% with cylindrical rod. Hajian et al. [27] investigated effects of magnetic field orientation on ECDM performance and concluded that magnetic field orientation increased channel depth and surface quality. Behroozfar and Razfar studied characteristics on the plasma channel and material removal [28] and tool wear [29] during ECDM. Zhang et al. [30, 31, 32, 33, 34] developed new process, tube electrode high-speed electrochemical discharge drilling (TSECDD), shown in Fig 3, to machine cooling holes. Low-conductivity salt solution [30] enhanced machining surface and efficiency, increasing tube-electrode inner diameter increased MRR [31] on TSECDD. The performance of ECDD with super-high-pressure interior flushing [33] and internal and side flushing [34] were investigated with machining parameters effects.

Dhanvijay and Ahuja [35] studied machining parameters of stagnant and electrolyte flow method on ECDM and obtained the results that electrolyte flow method had a high MRR but a high diametric overcut that had been minimized. A mathematical model was developed by Kamaraj et al. [36] to predict the overcut of the surface that was important to protect the product dimensions. 304 stainless steel was drilled with ECDM process by Huang et al. [37] who established a new process using high-speed micro-electrode. Liu et al. [38] analysed the interpolar voltage and characteristics of current of a process using slotted metal wheel and mist-jetting electrolyte in ECDM to stabilize. Krötz and Wegener [39] developed a new process that was spark assisted electrochemical machining (SAEM). This process was stimulating more contact arcs in a period on the contrary of ECDM. This method presented that the finishing could be done with the same equipment.

III. CONCLUDING REMARKS

The aim of this study was analysing the ECDM investigations and new processes of ECDM. Researchers, especially investigated and emphasized the material removal rate that was very crucial to improve the ECDM process. It was seen obviously that applied current [15] is the most effective parameter on MRR. New tools [10], tool shapes [7] or new processes [26, 35] were developed to enhance MRR. Besides, applied voltage is very effective on MRR [9]. Yet, Cao et al. [18] emphasized that high voltage reduced the machining
resolution. Future works will be carried out in ECDM in the light of the results.

REFERENCES

Comparative Analysis of Traditional Production Systems with Flexible Manufacturing Systems

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Abstract— Nowadays technology is developing rapidly and the adaptation of emerging technology to daily life is very fast. Within this context, production technologies are developing rapidly and parallel to this production instrument's costs are decreased. In this way, producers can make investments more easily by getting current technology. In parallel with industrial development, some parameters such lost time, labor, raw materials must reduce. When considering expected product variety, especially modification on the produced product is a difficult process. Revising of the production system according to the final product is substantially increased the amount of lost time. In addition, in this revision process previously realized investment is becoming inert and this quite increases costs. It is almost impossible the creation of a separate production line for each product in a company which has a lot of variety of products. Nowadays in this needed speed production process, instead of conventional production systems flexible manufacturing systems began to be preferred in the industry.

In this study, functions, components and the overall structures of the flexible manufacturing systems are described. Differences between traditional production systems and flexible manufacturing systems, and the advantages relative to each other were examined. In the study, Flexible Manufacturing Systems Laboratory within the Inonu University Arapgir Vocational High School was taken as an example.

Keywords— Flexible manufacturing systems, traditional production systems, factory organisation

I. INTRODUCTION

One of the major environmental factors that directly affect activity of the business is the economic system adopted by the country where the business [1].

Industrial businesses are organizations that meet the demands of customers, carry out the production function for it. Businesses should develop and establish a proper system for needs when performing their production.

Production Process is a process in which the materials are introduced as output after certain changes. Other processing activated where a process finished. As soon as a process starts the previous work is completed. Operations can be specified as a node and all the nodes constitute input-output system. [2]

A. Traditional Manufacturing Systems

The construction of traditional manufacturing systems is shown in Figure 1.

![Fig 1 Traditional manufacturing systems [1]](image)

It can be said to show a hierarchical structure of production systems. It is often used in the creation of this system is a hierarchical design approach. This approach can generate significant demand and limited production capability well in environments in which the solutions, but not enough. Classic hierarchical type of production structures, the not fully compatible with dynamic environment and leads to degradation in performance.

Traditional production types are summarized in comparison in Table 1:

<table>
<thead>
<tr>
<th>Machine Types</th>
<th>Features</th>
<th>workshop-type production</th>
<th>Flow-type production</th>
<th>Project-type production</th>
<th>continuous-type production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible, general-purpose</td>
<td>Flexible, general-purpose</td>
<td>Special, Mono-functional</td>
<td>General-purpose, Mobile</td>
<td>Special</td>
<td></td>
</tr>
</tbody>
</table>
Rapid changes in the technologies increase the efficiency of computer in the production and positive role of being used mathematical models in the production have attracted the attention of business owners and managers.

Some developments emerging in production can be summarized as follows:

- Computer Aided Manufacturing System
- Flexible Manufacturing Systems
- Material Requirements Planning
- Manufacturing Resource Planning
- JIT Production System
- Synchronized Manufacturing

B. Flexible Manufacturing system

Flexible manufacturing systems is defined as the production process can respond, automation and technology-intensive production is done, can be quickly directed to the production of production factors, the products are delivered to customers on time and can be rapidly respond to changes [3].

General characteristics of flexible manufacturing systems can be listed as follows:

- FMS can be used in business which has more varieties of products.
- FMS is used to produce different parts that in the same group.
- It includes general-purpose machinery and machine tools. Small scale changes can be made in the machine/equipment to produce different parts.
- Finished products, semi-finished goods and raw materials are able to move with automatic band and the carrier.
- A main computer controls the general-purpose machinery/equipment and material transport system.
- Production of different parts is possible with automatic changes on the machine.
- Staff intervention on production is minimized.

- From raw material input to finished product output, all process such as quality control, design, production are carried out the basis automation.

The definitions contained in different sources of FMS are as follows:[4]:

FMS is considered as the application of the Computer Integrated Manufacturing (CIM) concept, which composed from Computer Aided Design (CAD), Computer Aided Manufacturing (CAM) and Computer Aided Process Planning (CAPP).

FMS is an automated production type controlled by computers which designed for to produce more than one type parts effectively, consisting of the semi-independent workstations and material handling systems.

Main factors affecting the level of flexibility of a business can be listed as follows:

- Work Organization,
- Production Planning and Control Systems,
- Manufacturing Technology,
- Utilization Level of Computer Technology.

II. FLEXIBLE MANUFACTURING SYSTEM MODULES AT ARAPGIR VOCATIONAL SCHOOL

General view of Flexible Manufacturing Systems Laboratory

![Fig 2 General view (front)](image)

![Fig 3 General view (back)](image)
B. Testing Station

The Testing station detects the various properties of the work pieces inserted into it. It differentiates work pieces with the aid of an optical and a capacitive sensor [5].

C. Separating Station

The Separating station differentiates work pieces based on their drilled hole depth and separates them into two different material flow directions [5].

D. Processing Station

In the Processing station, work pieces are tested and processed on a rotary indexing table. On the rotary indexing table, the work pieces are tested and drilled in two parallel processes. A solenoid probe checks that the work pieces are inserted in the correct position. During drilling, the work piece is clamped. Finished work pieces are passed on via the electrical sorting gate [5].

E. Robot Station with MPS® Modules

This equipment level is created based on the basic design of the MPS® robot station and the two robot handling and robot assembly modules as an introduction to industrial robotics. The upstream station feeds the bodies of the pneumatic cylinders to be assembled to the robot via a slide. The robot determines the orientation of the bodies and places them in the assembly holder in the correct orientation. It takes the piston from the pallet and assembles it in the body. Controlled magazines feed the piston springs and cylinder end caps to the robot. The fully assembled pneumatic cylinder is then placed on a slide [5].
F. Assembly Station

The assembly station works in conjunction with the robot station. It supplies cylinder components for the assembly process [5].

![Assembly station]

G. Handling Station

The Handling station, electrical, is equipped with a flexible two-axis handling device [5].

![Handling station]

H. Pick & Place Station

The Pick&Place station is equipped with a two-axis Pick&Place module. Work piece housings placed on the conveyor are detected by an optical diffuse sensor. The work piece is transported to the pneumatic separator on the conveyor and detected by a second diffuse sensor. The Pick&Place module picks up a work piece insert from the slide and places it on the work piece housing. The complete work piece (housing and insert) is released by the separator and transported to the end of the conveyor [5].

![Pick & Place station]

I. Fluidic Muscle Press Station

The Fluidic Muscle Press station presses work piece inserts into the housings. The rotary/linear actuator (transfer device) moves the housing with the insert placed on it under the press. The pneumatic muscle performs the pressing operation. The finished work piece is then transported to the transfer position [5].

![Fluidic Muscle Press station]

J. Sorting Station

The Sorting station sorts work pieces onto three slides [5].

![Sorting station]
III. CONCLUSIONS

In this study, images of the equipment, experiment sets are designed by Festo Didactic training purposes. Each module can be matched with other modules. In this way it is possible to obtain improved diversity of the final product.

The manufacturing sector is constantly evolving according to evolving technology and growing needs. Requested product diversity has led to become outmoded of a single type production line. Therefore, instead of building new production lines to produce different types of the same product, revising this line is easier. In this regard with flexible production systems efficient results are obtained. Despite the high investment costs, in the long term it is seen that provided gain at costs and time.

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Electronics of a Holonomic Rescue Robot with a Screw Drive Mechanism for Soft Terrain Mobility

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Abstract—In rescue robotics, one of the most important features of the robot is the mobility, where the robot must be able to move inside the rubble to reach victims. In order to accomplish the difficult task of mobility, robots with different drive mechanism principles are built: ranging from serpentine motion to wheeled and tracked platforms. Another important feature of the mobility is holonomy, where the robot can move in any desired direction so that it can maneuver better in tight spaces. This paper reports design, prototyping and testing stages of a new mobility mechanism, namely a screw wheel drivetrain, where the wheels of the robot are screw shaped wheels. The special wheel design allows the robot to be holonomic and to perform well on soft terrain. The test results on the prototyped robot prove the system efficiency.

Keywords—Holonomic; screw wheel drive; rescue robot design; soft terrain mobility

I. INTRODUCTION

In the literature, rescue robots are designed to go over rough terrain with a high load carrying capacity [1]. However, when dust and broken pipelines are considered, the earthquake zone is a rather soft terrain and the mobility of the robot plays a vital role in the success of the mission. The real challenge in the design phase of a rescue robot is how to fit the necessary parts into the given dimensions so that the robot's size can be as small as possible and the load carrying capacity can be as high as possible. Since the distance needed to be traveled inside the rubble is not long, the speed of the robot is not so crucial. Especially when it is considered that a rescue robot needs to travel in a confined space, mobility becomes one of the most important features of the robot [2].

In this research, the mobility problem is solved with a holonomic drive mechanism, where the robot has the ability to maneuver inside a tight space because it can move in any desired direction with operator control. The uniqueness of the drive system is the wheel structure where the wheels are screw shaped and the driving motors are placed inside the wheels to create a more stable structure.

The drive mechanisms of rescue robots are wheeled, tracked, legged or any combination of these different systems [3, 4, 5, 6 and 7]. Shifting the center of gravity has also proven to help the mobility of the robot [8 and 9]. Moreover, there are also robot designs where serpentine and inchworm mechanisms are utilized [10 and 11]. The robots are compared to each other with many performance criteria such as: overcoming geometrical difficulties, volume capacity, weight capacity, energy necessity, reverse fall, failure durability, weight, dimensions, clearance, maneuver capability, falling resistance, velocity, number and size of motors, control difficulty, programming ease and manufacturing ease [12]. Even though it is not clear to the rescue robotic researchers which driving mechanism is better than the other, since different tasks will give different importance factors to the different properties, the mobility (overcoming geometrical difficulties) has the highest priority since the robot cannot achieve its task if it cannot reach to the desired operation point.

In order to solve the problem of mobility inside a confined space, omni-directional ability becomes very important. Omni-directional ability is reported in the literature with a spherical robot [13], differential drive [14], ball wheels [15], Synchronous drive [16] and Mecanum wheels [17] Fig. 1.

Spherical robots look like balls and they have the propulsion mechanism inside them. Just like a real ball they can roll in any direction over the terrain. However, the traction force is limited when it is compared to tracked robots. In order to increase the traction force, soft material is used for the outside wall of the robot, increasing the surface area of contact. The success of spherical robots is not clear because they are still at the ongoing research stage [13].

Differential drive robots consist of two independently driven wheels and robot body supporting castors. These types of robots are not completely holonomic, since they need to turn first in order to be able to move to the desired direction. This drive mechanism is good for indoors, but struggles outdoors, since the robot is a wheeled robot [14]. Tracked robots also act as differential drive robots but they have the same problem of not being holonomic.

In a ball wheel drive mechanism, the ball which has contact with the ground is driven by other interior wheels. Holonomy can be achieved, but when sand, mud or grass stick on the ball, the system’s characteristics change. Another fundamental problem with the ball wheel drive mechanism is that the theoretical clearance of the robot body can only be as high as the radius of the driven ball since the ball needs to be supported by the body of the robot in order to not fall [15].
A synchronous drive system is similar to a ball wheel drive system in that the wheels are driven by motors and they rotate about their own axis, usually with a belt or chain system. From the mobility point of view, a synchronous drive is not different than a ball wheel drive. On the other hand, the clearance of the robot can be increased if the drive motors are attached to the legs; however, this type of a robot is still a wheeled robot, where holonomy is achieved but the wheeled body disadvantages still exist.

The Mecanum wheel has a driven hub and idle rollers around it, which are 45 degrees to the axis of the hub. Typically 4 wheels are used on a vehicle where two left and two right handed wheels are used. When the wheels are driven in any direction, the vehicle can move and rotate in any desired motion.

Soft terrain can be described as a surface where the slippage and sinking occurs at the wheels of the robot. Sand, grass, mud, gravel, dirt and snow covered surfaces can be named as soft terrain. Slippage causes a difference in between the traction forces at the drive wheels, causing an orientation effecting the steering are explored and the parameters of the steering are explored as well as wheel model and wheel grousers design.

There are early screw wheel design robots; however, one design still uses rollers around the drive wheel which will have similar problems as Mecanum wheels and the other design lacks the kinematic and dynamic analysis, the control design as well as the total concept of skidding control in this type of structure.

The contribution of this paper is that it reports a prototype rescue robot especially designed for soft terrain mobility with a unique screw drive mechanism. In the following sections, the problem definition, the mechanical design and prototyping of the new screw driven omni-directional robot, the electronics system design and programming are explained. Test results prove the effectiveness of the concept and the necessity for slippage control.

II. PROBLEM DEFINITION

Soft terrain can be described as a surface where the slippage and sinking occurs at the wheels of the robot. Sand, grass, mud, gravel, dirt, snow, ice, dust and clay on the surface makes the surface a soft terrain. Slippage causes a difference in between the traction forces at the drive wheels, causing an orientation...
and speed error during the trajectory tracking of the robot body. Sinking of the wheels into the soft terrain also causes nonlinear traction forces and the has the same effect as the slippage. Moreover, the traction force generated by the wheels may not be enough for the robot to move again. Another issue with the wheeled, legged and tracked drivetrain systems is that the particles get inside the driving mechanism and stop the robot to work.

When other robot platforms’ performance on the soft terrain is investigated, the weight on the unit tire area becomes the most important factor. If the unit weight becomes higher, sinking occurs and if the unit weight is too less, the possible traction force which can be generated from each tire becomes too less to generate motion [27].

Spherical robots have a weight shifting mechanism inside the robot where by moving the center of gravity, moment is generated to roll the robot on the ground. The all-closed design gives the robot the advantage not being affected by the outside surface; however, the moment which can be generated is limited, causing the robot to have traction problems [13]. Differential drive, ball wheel, and synchronous drive are all wheeled robots. These robots are good for indoors but soft terrain such as sand, dirt, mud and grass stop these types of driving mechanisms. About Mecanum wheels it is reported that, slippage and vibration occur. Moreover, the ability to overcome obstacles is dependent on the direction of the motion [28]. In practice, sand and mud get stuck and stop the barrels to work on the Mecanum wheels.

Tracked robots have a bigger surface area to distribute the weight of the robot on the surface. However, sand, gravel, mud and grass get caught in between the drive train elements, the driven wheels and the track. Even in the track system with an idler, the mud or wet grass sticks to the innersection of the track and causes the track’s inner length to decrease. Since the position of the driving and driven wheels are not changed; the idler, if it exists responds. When the idlers cannot respond anymore, the pulling force on the track increases until the track breaks.

Another problem observed in practice is that the pulling resistance of grass is very high compared to its cutting. On grass terrain, when the robot is moving, the grass gets caught in between the rear wheel and the track. It does not rip apart and it can stop the robot if the robot cannot provide enough traction force to tear apart the grass.

A spring shaped wheel robot is reported [29] where the robot has 3 compression spring shaped wheels, aligned 120 degrees to each other around the platform. The robot is designed for rough terrain and since the wheels in this design are not filled inside, the pressure of the robot weight is not distributed to a wide area, so the robot will sink in soft ground. Moreover, because there are 3 screw wheels, the control is more difficult when it is moving in any given direction and the motors cannot be used at their highest speed.

In order to create a reliable platform to drive on soft terrain, a screw wheel driven robot is designed, manufactured and tested. The following sections explain the theory of the new wheel design as well as the physical manufacturing of the robotic system.

III. SCREW DRIVE ROBOT DESIGN, DYNAMICS AND CONTROLLER

The screw drive robot has 4 independently driven wheels with a screw shape allowing the robot to have the holonomic ability to move on the surface, Fig. 2 [30].

When the dynamical model of the robot is derived the equation of motion is found as

\[
D \ddot{q} = f(\dot{q}, \mu_i) + g(\dot{q}, \mu_i, \tau)
\]

(3.1)

where \(\mu_i\) is the friction coefficient effecting the \(i\)th wheel, the state vector \(\dot{q}\) and the control input vector \(\tau\) are formulated as \(\dot{q} = [u, v, r]^T\) and \(\tau = [\tau_1, \tau_2, \tau_3, \tau_4]^T\). The positive definite mass matrix \(D\), the term containing the unaffected dynamics from the control input \(f(\dot{q}, \mu_i)\) and the term containing the controllable dynamics \(g(\dot{q}, \mu_i, \tau)\) are formulated respectively as

\[
D = \begin{bmatrix}
    m & 0 & 0 \\
    0 & m & 0 \\
    0 & 0 & J
\end{bmatrix}
\]

(3.2)

\[
f(\dot{q}, \mu_i) = \begin{bmatrix}
    -mrv + CA(\mu_i - \mu_2) - CB(\mu_i - \mu_4) \\
    \frac{1}{R} (\tau_1 + \tau_2 + \tau_3 + \tau_4) \\
    \frac{1}{R} (\tau_1 - \tau_2 - \tau_3 + \tau_4) \\
    \frac{1}{R} (\tau_1 + \tau_2) + \frac{1}{R} (\tau_3 + \tau_4) - \frac{1}{R} (\tau_1 - \tau_2 + \tau_3 - \tau_4)
\end{bmatrix}
\]

(3.3)

\[
g(\dot{q}, \mu_i, \tau) = \begin{bmatrix}
    \frac{1}{R} (\tau_1 + \tau_2 + \tau_3 + \tau_4) \\
    \frac{1}{R} (\tau_1 - \tau_2 - \tau_3 + \tau_4) \\
    \frac{1}{R} (\tau_1 + \tau_2) + \frac{1}{R} (\tau_3 + \tau_4) - \frac{1}{R} (\tau_1 - \tau_2 + \tau_3 - \tau_4)
\end{bmatrix}
\]

(3.4)

A and B are described as

\[
A = \arctan\left(\frac{v + r l_f}{u - r l_i}\right)
\]

(3.5)

\[
B = \arctan\left(\frac{v + r l_f}{u - r l_i}\right)
\]

(3.6)

where \(m\) is the robot mass and \(J\) is the moment of inertia about the vehicle mass center, where \(r\) indicates the wheel, \(ti\) is
the driving torque applied to the i’th wheel and R is the wheel radius, u is the longitudinal velocity; v is the lateral velocity, \( \mu_d(\sigma) \) is the road surface friction coefficient which is a function of \( \sigma \) wheel slip ratio and \( l_p \) and \( l_r \) are the distances between the CM location and the front and the back axles respectively.

An adaptive controller is designed as

\[
\tau_d = Y \hat{\theta} - K_D \dot{s}
\]  
(3.7)

where \( K_D = K_D^T > 0, K_D \in R^{3\times3} \) is a gain matrix, \( \hat{\theta} \) is the estimate of \( \theta \), updated from an adaptive law. This control law could also be used for the ideal system \( D \dot{s} = -Y \theta + \tau_d \).

With the control law (3.7), the closed-loop system is

\[
D \dot{s} = Y(\theta - \theta_1) - Y_1(\theta_1 - \theta_2) - K_D \dot{s}
\]  
(3.8)

in which to design an adaptive control scheme to handle parameter uncertainties, for \( \dot{q} = [u, v, r]^T \) and \( \dot{q}_d = [u_d, v_d, r_d]^T \), the tracking error \( e \) and the filtered tracking errors \( s \) and \( \dot{s} \) are defined as

\[
e = q - q_d, \quad \dot{e} = \dot{q} - \dot{q}_d
\]
(3.9)

\[
s = \dot{e} + \eta \dot{e}, \quad \dot{s} = \dot{e} + \eta \dot{e}
\]  
(3.10)

where \( \eta \in R^{3\times3} > 0 \) is a diagonal gain matrix, \( K_D = K_D^T > 0, K_D \in R^{3\times3} \) is a gain matrix,

\[
Y(\hat{q}, \dot{q}, h) \in R^{3\times6}
\]

is a known parameters matrix function, \( \theta(m, J, \mu_1, \mu_2, \mu_3, \mu_4) \in R^{6\times1} \) is an unknown parameter vector and is formulated as

\[
Y(\hat{q}, \dot{q}, h) = \begin{bmatrix}
h_\text{e} & rv & 0 & 0 & 0 & 0 \\
h_\text{e} & rv & 0 & -CA & CA & CB & CB \\
0 & h_r & \dot{h} & CA & l_rCA & l_rCB & l_rCB \\
\end{bmatrix}
\]  
(3.11)

\[
\theta = [m, J, \mu_1, \mu_2, \mu_3, \mu_4]^T
\]  
(3.12)

**IV. ELECTRONIC SYSTEM DESIGN**

The remote control of the robot is achieved by use of a joystick, which is in fact a combination of analog and digital input devices. A standard Arduino joystick shield is used, which has 4 momentary push buttons to select and one 2 axis thumb joystick. The thumb joystick is in fact a potentiometer where with the motion of the thumb joystick, the resistance value changes and the position of the joystick can be concluded. Under the 2 axis thumb joystick, there is another built in select switch. This built in select switch becomes very handy, when the joystick is intended to control the rotation of the robot. The first 2 axis are controlled without using the built in select switch. The robot is driven on a 2 dimensional surface. When the robot is desired to be rotated about its own axis, the select switch is used to trigger the program and the joystick can start to control the motors in such combination that the robot turns clockwise or counterclockwise.

The motion of the joystick is transferred into command signals with the joystick microcontroller and it is transferred to the robot with a wireless unit, a Xbee 2.5 module. The parts of the joystick unit are shown in Fig. 3. By using Xbee shield and Joystick shield, it is possible to have a joystick unit with no connection wires, which is therefore less likely to fail.

When the robot is driven on soft terrain, random slippage occurs at any wheel. When the dynamical equations are carefully studied any change of the friction coefficient \( \mu \) causes trajectory tracking error of the robot platform position. The velocities of the platform in lateral and longitudinal axes and the rotational speed about the z axis are the system parameters \( \dot{q} = [u, v, r]^T \).

In order to measure these parameters a 6 axis IMU is used [31]. This sensor (SEN-10121) occupies an ITG3200 triple-axis digital output gyro where the rotational change \( \dot{r} \) measured and anADXL345 triple axis accelerometer where the acceleration in lateral and longitudinal axes \( \dot{u} \) and \( \dot{v} \) are measured. The integration of these measured variables provides the system parameters.

The wheel motors are driven with motor driver boards, namely MC33926, [32]. This H-bridge provides current feedback which is used to calculate the momentary motor torque \( \tau \), with the motor model.

The data received from the IMU unit and the current feedback from the motor drivers provide the necessary information to apply the control logic. For the application of the control algorithm an Arduino Mega 2560 with an ATmega2560 AVR microcontroller is used, [33].
direction is controlled with the joystick position. Toggling the switch makes the joystick program switch from surface motion to rotational motion. In rotational motion the robot turns about its own axis clockwise or counterclockwise.

The motion of the joystick and the switch position describe which signals are to be sent to the robot and the decoded signal is used to drive the motors. Table I shows which commands are sent from the joystick microcontroller to the robot microcontroller and how the motors turn and the robot moves. When the robot is stopped, the joystick sends “5” as a stop signal.

VI. TEST RESULTS

The wheels of the robot rotate like Mecanum wheels and Table I shows the directions of the motors depending on the desired robot motions. Tests conducted in which the steering, mobility, load capacity, remote control, endurance, weight, speed, incline angle and rolling angle of the robot were evaluated.

On the soft terrain, the robot performs very well, since weight distribution is achieved. When the weight of the robot (4020 grams) and the wheel dimensions (70 mm diameter) are considered, the robot has 0.095 gr/mm2 pressure at the maximum sink level. This low pressure level at the wheels allows the robot to drive well on the soft terrain, allowing it to stay on the surface of a sandy terrain.

When the robot moves on muddy or grassy ground, the grass does not cause any problem since it cannot get in between the moving wheel and the stationary drive motors. Inside each wheel unit a Dunkermotoren G30.2 motor with a PLG 30 gearbox is used where the rated speed of the motor is 3000 r/min and the reduction ratio is 36. Considering the wheel diameter being 70mm, the theoretical speed of the robot is calculated as 18.32 m/min. However, in reality the speed of the robot in longitudinal axis is found as 5.2 m/min and in lateral axis is measured as 16.4 m/min. The speed difference comes from the different working principles of the wheels in these different axes. In lateral motion, the wheels are rolling and the speed of the motor is close to the theoretical speed. However, in longitudinal motion, the screw threads need to move the robot and because of the slippage, the speed of the robot decreases. On a muddy surface, the speed of the robot decreases in both directions, but the decrease depends on the surface friction and cannot be compared to the flat surface speed.

When the robot is moving on a hard surface, lateral and longitudinal motions do not have significant slippage. However, longitudinal motion has a slippage problem, causing the robot steer to the right or left depending on the surface friction difference. The robot requires on board slippage control to adjust the wheel speeds to compensate for skidding errors. In order to eliminate the slippage errors, the track depth on the wheels can be improved for better traction, at the moment the depth is 3.5 mm and the width is 10 mm. The wheel surfaces can also be improved by covering the surfaces with softer material to achieve better traction.

The wireless connection is achieved with an XBee module and it is measured that within 112 meters in an open field it could receive reception. Inside a building, because of the walls, this distance drops down to 14 meters. The wall thickness and quality changes the reception distance.

The robot motors require a total of 0.78 ampere current on a flat surface with 12V DC. Considering the battery has a 3.2 Amphour energy capacity, the robot has approximately 4 hours of endurance. On the experimentation, the robot battery was able to last 2.7 hours and when it was measured the voltage level was at 9 Volt. At this voltage, the motors cannot generate meaningful moment to drive the robot anymore on a soft terrain.

Ditching capacity is measured and found as 140 mm, which is higher on the lateral direction of the robot. Load carrying capacity of the robot depends on the brackets connecting the wheels to the main body plate. 3 kg is successfully carried by the robot, but a change in center of gravity should be taken into consideration when the load is placed at the back or the front of the robot.

The center of gravity is at 56.88 mm above the surface where the clearance of the robot is 65 mm. This low center of gravity assures the robot to be stable on a tilted surface. However, when compared to the theoretical sideways (65.53 degrees) and frontward tilting angles (80.68 degrees), the actual sideways angle is 17.033 degrees and frontward tilting angle is 11.655 degrees measured on a wooden surface. The reason for this difference is the friction coefficient in between the surface and the robot wheels. This fact also shows how the current wheel material, polyethylene, is good for manufacturing but not suitable for traction reasons, and the wheels should be covered with a softer material.

The wheel brackets play a vital role on clearance, center of gravity and load capacity of the robot. Increasing the height of the brackets will increase the clearance; however, it will also

<table>
<thead>
<tr>
<th>Joystick Motion</th>
<th>Toggle Switch</th>
<th>Joystick Command</th>
<th>Motor 1</th>
<th>Motor 2</th>
<th>Motor 3</th>
<th>Motor 4</th>
<th>Robot Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>Off</td>
<td>8</td>
<td>CCW</td>
<td>CCW</td>
<td>CCW</td>
<td>CW</td>
<td>Forward</td>
</tr>
<tr>
<td>Backward</td>
<td>Off</td>
<td>2</td>
<td>CCW</td>
<td>CW</td>
<td>CCW</td>
<td>CCW</td>
<td>Backward</td>
</tr>
<tr>
<td>Right</td>
<td>Off</td>
<td>6</td>
<td>CW</td>
<td>CW</td>
<td>CCW</td>
<td>CCW</td>
<td>Right</td>
</tr>
<tr>
<td>Left</td>
<td>Off</td>
<td>4</td>
<td>CCW</td>
<td>CCW</td>
<td>CW</td>
<td>CW</td>
<td>Left</td>
</tr>
<tr>
<td>Right</td>
<td>On</td>
<td>66</td>
<td>CW</td>
<td>CW</td>
<td>CW</td>
<td>CW</td>
<td>Right</td>
</tr>
<tr>
<td>Left</td>
<td>On</td>
<td>44</td>
<td>CCW</td>
<td>CCW</td>
<td>CCW</td>
<td>CCW</td>
<td>Left</td>
</tr>
<tr>
<td>Center</td>
<td>On or Off</td>
<td>5</td>
<td>Stop</td>
<td>Stop</td>
<td>Stop</td>
<td>Stop</td>
<td>Stop</td>
</tr>
</tbody>
</table>
Fig. 4 Tracking performance in the X axis (longitudinal motion).

Fig. 5 Tracking performance in the Y axis (lateral motion).
raise the center of gravity, causing the sideways and frontal tilting angles to decrease. Making the brackets from thicker material will only increase the weight of the robot by fractions; however, it can improve the load carrying capacity.

Since the robot motion is created when the wheels are cancelling lateral motion when it is moving on the longitudinal axis, the tracking error needs to be compensated on both axes at the same time. In order to test the controller efficiency, the tracking performance of the robot motion is tested both in the longitudinal and lateral axes on the flat sandy surface. The reference trajectory input is given as programmed and the actual value of the trajectory is measured via IMU.

Fig. 4 and Fig. 5 shows the longitudinal and lateral motion respectively. Both in Fig. 4 and Fig. 5, the red line shows the reference trajectory while the blue line shows actual trajectory. In Fig. 4 at first 6 seconds while the robot is only moving in longitudinal direction the tracking is achieved as seen on Fig. 5 the motion on the lateral direction is also successfully cancelled to keep the lateral tracking as desired. Similar trajectory tracking is achieved in between 8 to 15 seconds while the lateral tracking is controlled, longitudinal tracking is also achieved.

VII. CONCLUSIONS

In this study a screw wheel drive mechanism for a rescue robot is examined. This design is durable for soft terrain especially for sandy, muddy and grassy surfaces. The wheel structure as well as the mechanical and electrical structures of the robot are explained in detail. A physical prototype was built and tested for mobility, speed and endurance. The test results show that the screw wheel drive mechanism works well on soft terrain conditions. Because of the different slip ratios at each wheel a controller was implemented to compensate for the tracking error.

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DESIGN AND MANUFACTURING OF A MICRO-TENSILE TESTER

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Abstract—One of the most common used methods for determining mechanical properties of engineering materials is tensile test. In this study, portable micro tensile tester that low strength materials have enough capacity to do tensile tests has been designed and produced. Stress and strain in tester have been real time followed by wireless communication with an interface prepared in LABVIEW. Performed tester is workable-sized with needed atomic force microscopy to study micro- and macro structure of materials together. Due to being portable-sized of tester, it can be used in classroom in materials science education. Snapshot of sample and stress-strain curve are real time followed with the camera placed on the tester at the same time.

Keywords— tensile tester, tensile test, mechanical properties, stress-strain behaviour, material science education

I. INTRODUCTION

Deformations on the material under the effect of external forces and endurance strength that the material showed under the said effects are named as mechanical properties of materials. Mechanical properties of materials are a very important factor in engineering designs.

The most common testing method used in determination of mechanical properties of materials is tensile test [1]. In a tensile test, test samples prepared are held from their two edges and exposed to the load by uniaxial tensing [2]. Data of strength and elongation generated on the sample are recorded during the test. Tensile test ends upon the breakage of the test sample.

The tester used in order to examine micro structure of materials are named as atomic force microscope (AFM). In order to design and manufacture micro and nanocomposite materials, the connection between mechanical properties of material and the microstructure should be understood well [3]. In this study, in order to understand the connection between microstructure and mechanical properties of materials, a portable horizontal micro tensile tester has been developed, which provides the association between AFM and the tensile test. Standard testers are usually positioned vertically and are in large scales. Those sorts of testers are not possible to work with AFM.

In order for mechanical properties of materials to be understood and evaluated by students can be difficult. The tester carried out can be used in classroom in materials science education due to its portability unlike other testers. During the test, in order to help students to understand mechanical properties of materials, a camera has been placed on the tester. In this way, snapshot of changes in the material during the test and strength and elongation data of the material can be real time followed. Control of the tester has been performed via Programmable Logic Controller (PLC). In order for elongation and load data to be displayed and for tester to be controlled by the user, an interface has been designed on LabVIEW platform. For the communication between the interface and PLC, OLE for Process Control (OPC) has been used.

II. DESIGN OF THE TENSILE TESTER

A. Design Concept

Block diagram of the tensile tester carried out in the study is given in the Fig. 1 A test sample connected to the tester is exposed to a tensile stress at a speed determined by the user. Tensile stress is performed with the step motor’s spinning and the moving holder’s advancing. Deformation and load are emerged on the sample remained between the fixed and moving holder. Elongation data occurred on the sample is measured via magnetic linear encoder respectively. Strength occurred on the sample is measured via load cell. With the data obtained, stress-strain behavior belonging to the sample is acquired.

On the simplified drawing of the mechanism of the tester given in the Fig. 2, upon the rotation of the propulsion motor F, the movement is transferred to the thread rod B over belt-pulley H. Upon the thread rod starting to spin, panel C moves and generates tensile stress on the sample A. Stress on the sample is measured via load cell E. Amount of elongation occurred on the sample is measured via magnetic linear encoder connected to the moving panel.

In order to generate tensile stress, single threaded rod embedded with linear rails on two sides has been used on tester. The reason for preferring the single threaded rod is to ensure the stress axis being equal on the sample. Possible deflections will occur on sample edges equally and simultaneously [3]. It guides linear rails and the moving clamps of the tester to advance through the movement axis linearly. Belt-pulley mechanism on the device, has been preferred instead of coupling connection in order to prevent the increase in linear size of the tester. This tester has been designed in micro size
and horizontally in order for AFM to be able to take images over the sample.

Before manufacturing the tensile tester, three-dimensional modeling of all electronic hardware and mechanical parts on the device has been performed. Thanks to three-dimensional modeling, faults that may occur after the manufacture have been determined and possible financial losses have been prevented. Mechanical parts that could not be off-the-shelf procured have been manufactured at CNC vertical processing center. Modeled image and manufactured image of the tester is given in the Fig. 3.

B. Load Measurement

The amount of the load occurred on the sample during the test is measured via load cell branded CAS attached to the tester (e.g. Fig. 3). Load cell with 500 kgF capacity has been preferred due to its size and reasonable cost. Tensile stress sensitive load cell generates stress in proportion to amount of load that it carries. Stress generated has been connected to the analog inputs of PLC by using load cell amplifier.

C. Measuring Elongation Data

Amount of elongation occurred on the sample by the tester is measured via magnetic linear encoder (e.g. Fig. 4) The amount of elongation, occurred on the sample upon the advancement of the moving clamp attached under the moving clamp of the tester, is measured via magnetic linear encoder. Measurement precision of the amount of elongation is limited with the resolution of linear encoder. Resolution of elongation measurement of the tester is 5 µm. Encoder having transistor output produces pulse signal at every 5 µm distance. These pulse signals are applied to PLC inputs and each pulse signals are counted by PLC. At the end of these countings, amount of elongation occurred is calculated until the sample breaks off. Magnetic linear encoder has been preferred due to its very small size and reasonable cost. If the one wishes to increase the measurement precision, linear encoders with high resolution can be preferred.
D. Motor

In order to generate 3 kN maximum tensile stress with the tester, step motor with encoder and reducer having 3.0 Nm torque is used (e.g. Fig. 6). The motor used has 5:1 gearbox. Via the interior encoder connected to motor shaft, steps of the motor are followed and a new step is procured instead of the missing steps of the step motor. In this way, closed loop control is made and the reference speed determined is kept constant during the test.

Step motor used has 1.8 ° step range. The step motor is driven in a way that it would revolve 1 round with 40,000 pulse signal by using half-step driving technique. Based on the reduction rate of the motor, although theoretical advancement precision is in nm resolution with threated rod, measurement precision of the tester is 5 µm based on the linear encoder.

E. Control System

PLC devices are the devices that may contain all devices necessary for controller technique, that can do programming via both programming consoles and computers, and automatically control the automation system that we wish to control with the program written, and that work on the basis of the digital system. PLC system controls many machines and systems with its analog-digital input/output connections, and it is an integrated system that makes assignments to the output units by using numeric processes, and timing, numerator, data processing, comparing, sorting and input information for this purpose, and that consists of input-output, memory, CPU and programming parts. Additionally, there are many internal (assistant register) relays and time limit relays within the device.

Control of the tester has been performed via Siemens S7-1212C PLC. A product of Siemens firm, S7-1200 PLC has a project design software, and an Ethernet port for the purpose of easy connection and communication between controllers and HMI units. There are 6 high-speed numerators on S7-1200. 6 high-speed numerators, consisting of three-input 100 kHz and three-input 30 kHz, can be used in order for counting and frequency measurement. Four integrated high-speed outputs can be used in order to do pulse train (PTO) up to 100kHz speed or pulse width modulation (PWM). When it is set as PTO, it is possible to perform speed and position controls of servo or step motors. When it is set as PWM, it is possible to control the motor speed, position of the valve or the heater circuit.

PTO signal required for the control of the step motor in the tester is generated by PLC: With PTO, departure and halting ramps can be adjusted for advancing at desired speed in the linear system and for the step motor.

Linear encoder used on the tester has been connected to the high-speed input of PLC and elongation data is calculated based on these input signals. By turning load cell signals into digital signals via ADC input placed on the PLC, real time load measurements have been performed.

Control unit of the tester is assembled on the switchboard (e.g. Fig. 7). All connection wires between the switchboard and the tester are separated from each other via sockets. In this way, the tester is divided into two during replacement and can be carried by one person.
F. Graphical User Interface Software

In order to operate the tester and to follow the data, a user interface working on computer has been designed on LabVIEW platform. Through this software, programs are written via a graphical view by connecting functional dots to each other with the help of lines containing data flowing within. This programming language is named as “G”.

The user interface has been generated by providing communication between S7-1212C PLC used on the tester put into practice and LabVIEW software (e.g. Fig. 8) This communication is provided via NI OPC Servers which is a LabVIEW extension package supplied by National Instruments (NI). OPC (Ole for Process Control) is a standard constituted for the communication of real time data. It is used for the communication between SCADA systems and the devices, such as PLC, sensor and actuator which are used especially in industrial automation systems.

Memory spaces of S7-1212C PLC has been reached by using NI OPC Servers software. Control of the tester has been performed by conducting reading and writing processes on the determined memory spaces by the interface. Additionally, by using the extension named LabVIEW NI Vision Development Module, snapshot of the sample can be monitored on the interface screen via the camera on the tester.

The communication between PLC and LabVIEW has been provided by using Ethernet based wireless communication system. The device has been made available for access through wireless network by connecting an access point on the Ethernet port placed on PLC. In this way, the wireless connection between the interface and the tester is provided.

G. Specifications of the Tensile Tester

Samples in special sizes are used on the tester manufactured. Sample sizes and technical properties of the tester that can be used are given below:

- Maksimum sample size: 2mm thick, 80mm long, 10mm wide
- Minimum sample size: 0.1mm thick, 50mm long, 1mm wide
- Maksimum tensile force: 3.0 kN.
- Maksimum strain: %100 (for a 60mm long sample)

III. EXPERIMENTAL STUDIES

Via the tester manufactured, tests at various speeds have been implemented on acrylonitrile-butadiene-styrene (ABS) sample. ABS material is a light and firm polymer that is used in products manufactured with mold and 3D print technologies. Pipes, automotive parts, protective helmets and plastic parts of electronic devices are only some of its areas of use. The sample used in the tester has been manufactured by using 3D printer.

In experimental studies, the sample has been exposed to tensile stress at 1mm/min speed. At all of the separated tests, it has been determined that the maximum tensile stress, elasticity module and maximum elongation values occurred until breakage were matching to each other. Graphs obtained (e.g. Fig. 9), has been taken via interface generated on LabVIEW platform. Images of the same sample have been taken at 5mm/min speed. In the graph (e.g. Fig. 10) obtained, a significant amount of decrease in elongation of the test sample. It has been seen that the maximum tensile stress had been decreasing as a result of the tensile test (e.g. Fig. 11) conducted at 1mm/min on ABS material having a low fill rate.
IV. CONCLUSIONS

As a result of this study, a compact, low-cost and portable tensile tester has been realized. Considering its sizes, the tester can work under AFM. It has been determined that the stress should be at the same area while AFM is taking images. Best results would be gained by using two moving clamps on the tester manufactured, instead of one moving clamp. Due to cost increase, this modification will be performed later.

Due to reasonable cost, small sizes, wireless communication feature and integrated camera of the tester, it can be used in materials science educations.

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Robust Stabilization of a Servomechanism With Respect to Time-Delay

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Abstract— In this paper, a servomechanism subject to teleoperation is considered. Since the teleoperation itself can result in large amount of time-delays, it can be difficult to control such mechanisms in order to accomplish the desired task. From the robust control viewpoint, a methodology that guarantees the stability in worst case is essential. Based on a simple methodology to find the delay independent stabilizing gain regions, by forming the magnitude polynomial and employing the root locus technique, the stability of the robot is guaranteed, even in the worst case: the system becomes stable even if the connection has huge amount of time delays. This fact is evidenced first by the simulations. To perform the simulations, without any knowledge about the motor parameters, the motor is modeled by a global optimization methodology, named Genetic Algorithm in order to obtain a valid model for the system as accurate as possible. Then the resulting gains are applied to the real system, the results of which are found in accordance with the simulation results; the stability of the operation is not affected by the time-delay.

Keywords— Teleoperation System Control, Time-Delay Systems, Robust Control, Low-Order Controllers, Delay Independent Stability

I. INTRODUCTION

Teleoperation is one of the invaluable control methodologies which is especially ideal for the unfavourable environmental conditions, such as underwater or mountainous terrains and for the processes that is dangerous for human life, such as nuclear plants, toxic chemical reactions etc. This methodology has been more widely used especially for a few decades due to the advances of the internet based technologies [1]-[2]. Nevertheless, the most important drawback of this methodology is the phenomenon of the propagation time-delay, amount of which can be huge. Moreover, the amount of time-delay can be affected from operational conditions and hence can be changed operation to operation [3]-[7].

From the mathematical point of view, for Linear Time Invariant (LTI) and Single Input Single Output (SISO) systems, time-delay term adds infinite number of poles in the closed-loop. As a result, analyzing the performance of time-delay systems, even assessing the stability becomes more complicated in such systems [8]-[12].

As might be expected from the operational and the mathematical viewpoints, the amount of the time-delay may considerably attenuate the overall control performance, even it may lead the system to instability. As the stability is the first and the foremost important requirement of the design, an effective methodology providing the time-delay independent stability is essential from the robust control viewpoint.

In [13], an effective and simple methodology to compute all gains providing time-delay independent stability is given for SISO-LTI systems. This method is based on the stability analysis given in [8] and it consists of forming the magnitude polynomial, sketching the resulting root locus with the suitable transformations of the variables and searching the regions of gains for which any positive real roots do not exist.

Using the methodology given in [13], a servomechanism subject to teleoperation is considered in this paper. The motors are selected as Dynamixel MX-106T [14] and as the motor parameters are not explicitly given, the global optimization method, named Genetic Algorithm (GA) is employed to obtain a proper model of the motors. Then using the obtained mathematical model, all gains providing time-delay independent stability is computed as proposed in [13], and it is shown that the simulation results are as expected. To verify the simulation results in the real environment, the resulting gains are applied the servomechanism subject to teleoperation under different scenarios, i.e. for different values of time-delay. Then it is shown that, the application results are in accordance with the simulations, i.e. the stability of the system is not affected by the time-delay even if the time delay takes huge values, such as 12 seconds.

The paper is organized as follows: The second section is devoted to the theoretical background, in order for the readers to follow the paper easily. In this section, the methodology given in [13] is presented and the brief summary about the GA is given, respectively. In the third section, it is explained how
the mathematical model of the motors are obtained and the methodology given in [13] is applied to this model, i.e. all the gains providing time-delay independent stability is calculated. In the fourth section, the simulation and the real system results are shown, in a comparative manner. In the last section, further discussions are given and the possible extensions of this study is stated.

II. THEORETICAL BACKGROUND

In this section, the methodology for the computation of all gains providing time-delay independent stability proposed in [13] will be briefly explained and the Genetic Algorithms (GA) will be briefly overviewed, respectively.

A. Calculation of All Gains Providing Time-Delay Independent Stability Using the Root Locus

In this subsection, the methodology given in [13] will be briefly explained. Since this subsection is a summary only, the reader is referred to [13] for further discussions and explanations.

To begin with, let the interested control scheme is given in figure 1.

![Diagram](image-url)

Fig. 1 The interested control scheme

Where the G(s) and the C(s) is given as follows:

\[ G(s) = \frac{N(s)}{D(s)} e^{-st} = \frac{b_n s^n + \ldots + b_1 s + b_0}{a_m s^m + \ldots + a_1 s + a_0} e^{-st} \quad C(s) = k_p \quad (1) \]

Where N(s), D(s) and C(s) denote the numerator - the denominator polynomials and the P type controller respectively. Additionally, L symbolizes the nonnegative time-delay of the system.

Apparently, when L=0, i.e. the system is delay-free, the characteristic structure of the closed loop system constitutes a polynomial; i.e the closed loop poles are finite in number and it is easy to determine the stability of the system. However, when L takes the values greater than zero, the closed loop structure begins to constitute an expression named quasipolynomial, which possess infinite number of roots; resulting in infinite number of closed-loop poles. Additionally, these poles move in the s plane with the change of the L value.

To track these movements in terms of stability problem [8], let an infinitesimally small L is introduced to the system. In that case, the number of the closed loop poles become infinite, and these new poles appears at infinity in the s plane. From the stability viewpoint, all of these roots must occur in the left half s plane. To sum up, if the following conditions are satisfied, all the new roots occur in the left half plane:

i) m<n, i.e. the system is strictly proper, or

ii) m=n, i.e. the system is biproper and \(|k_p b_n/a_0|<1\)

In other words, if the system is strictly proper, all the new roots occur in the left half s plane without any further condition. If the system is biproper, an additional condition have to be satisfied about the ratio of the principal coefficients, i.e. \(|k_p b_n/a_0|<1\).

Assuming that either of these conditions are satisfied, the roots begin to move in the s plane with the increase of the L. When L reaches to a critical value, say Lcr, a pair of roots begin to locate on the imaginary axis just before changing their half planes, which is crucial as it implies a possible stability change. When such a situation happens, the closed loop expression satisfies the following equation:

\[ D(j\omega) + e^{-j\omega L}k_pN(j\omega) = 0 \Rightarrow e^{-j\omega L} = -\frac{D(j\omega)}{k_pN(j\omega)} \quad (2) \]

Obviously, this expression implies two condition to be satisfied:

\[ |-D(j\omega)/k_pN(j\omega)| = 1 \quad (3) \]

\[ \angle -D(j\omega)/k_pN(j\omega) = -\omega L \quad (4) \]

The first one can be considered as the magnitude condition, which determines the location of the closed loop pole pairs on the imaginary axis, just before changing their half planes. The second one can be thought as the phase condition, from which, the corresponding L value, i.e. Lcr is determined.

If the magnitude condition given in (3) is elaborated, the following equivalent condition can be obtained:

\[ W(\omega^2) := D(j\omega)D(-j\omega) - k_p^2N(j\omega)N(-j\omega) = 0 \quad (5) \]

As might be expected, the roots of this equation correspond to the solution of (3). Apparently, (5) is a polynomial of \(\omega^2\) implying that the closed loop poles crosses the imaginary axis as pairs by locating at \(\pm j\sqrt{\omega}\). Moreover, it is independent of L and its roots change with \(k_p\).

Clearly, the complete imaginary axis crossing of the closed-loop poles, i.e. possible stability changes with respect to time-delay are governed by (5). Then if there can be found some \(k_p\) values and/or regions such that (5) has no positive real roots, it can be stated that for these \(k_p\) values, no pair of closed-loop poles cross the imaginary axis i.e. there is no stability change. Since (5) is a polynomial that is independent of L, this situation does not change with the L values; implying that the stability of the time-delay system is not affected by the time-delay.

In this way, if (5) is elaborated, it can be observed that the problem can be converted into a simple root locus sketch. To accomplish that, let the following variable transformations are done in (5):

\[ v := \omega^2, \quad \alpha := k_p^2 \quad (6) \]

\[ A(v) := D(j\omega)D(-j\omega), \quad B(v) := N(j\omega)N(-j\omega) \quad (7) \]
If both sides of (5) are divided into A(v) along with the other transformations above, (5) can be rewritten as

\[ 1 - \frac{B(v)}{A(v)} = 0 \]  

(8)

Obviously, this defines a negative root locus in the v plane. The all needs to be done is to interpret this root locus whether there exists a gain values and/or intervals such that (8) has no positive real roots. If such an \( \alpha \) gain value and/or interval can be found, for those gains (5) has also no positive real roots, implying that no root pair can cross the imaginary axis, regardless of the value of L. Obviously, by considering (6), those \( \alpha \) gain values are squared gains and needs to be retransformed into \( k_p \) values again. Let such a squared gain interval \((\alpha_1, \alpha_2)\) is found for which (8) has no positive real roots. Then from (6), the corresponding gains can be given as the following intervals:

\[ k_p \in \left( -\sqrt{\alpha_2}, -\sqrt{\alpha_1} \right) \cup \left( \sqrt{\alpha_1}, \sqrt{\alpha_2} \right) \]  

(9)

To sum up, for those gains, the stability of the system given in (1) is not affected by the time-delay; if the delay-free system is stable (unstable) the time-delay system is stable (unstable) for all values of L.

**B. Genetic Algorithms (GA)**

Here, a brief overview of the Genetic Algorithms is given, and the reader is referred to [15] for much more detailed explanations.

Genetic Algorithms are known as their robustness and usefulness as optimization algorithms. In principle, GAs are search algorithms based on mechanics of natural selection and natural genetics. They combine survival of the fittest among the string structures with randomized yet structured information exchange to form a search algorithm with innovative flair of natural evolution [15].

In general, it can be mentioned that GA mainly works at three stages which are briefly described below:

1) **Reproduction**: The stage where the candidates are copied by their fitness function values.

2) **Crossover**: The stage where some parts of the candidates are changed within themselves.

3) **Mutation**: The where the randomization is applied.

**III. IDENTIFICATION OF THE SYSTEM AND THE CALCULATION OF THE TIME-DELAY INDEPENDENT STABILIZING GAINS**

In this chapter, it will be described how the system model is obtained and using the obtained mathematical model, the corresponding gains will be calculated employing the methodology explained in the subsection II-A.

**A. Identification of the System**

As mentioned before, the utilized motors are selected as the Dynamixel MX-106T. It is a permanent magnet direct current (PMDC) motor and all the necessary information and all operating conditions about the motor can be found in [14].

However, since the motor parameters are not explicitly known, a system identification process is taken into account from the real data obtained from the motors. However, before describing the identification process, it is desirable to discuss the model properties of the servomechanisms.

In general a permanent magnet direct current (PMDC) motor can be modeled by the following equations:

\[ \tau_m = \tau_L + J_m \frac{d\omega_m}{dt} + B_m + \omega_m \]  

(10)

\[ V_a = V_b + L_m \frac{dI_a}{dt} + R_m I_a \]  

(11)

\[ \tau_m = K_B I_a \]  

(12)

\[ V_b = K_s \omega_m \]  

(13)

where \( \tau_m \) and \( \tau_L \) represent the motor and load torque, \( J_m \) and \( B_m \) represents the equivalent inertia and the viscous damping at the armature, \( V_a \) and \( V_b \) represents the applied voltage and the back electromotive force (back emf), and the \( K_B \) and \( K_s \) represent the motor torque and the motor back emf constants, respectively. The corresponding block diagram of such a servomechanism can be seen in figure 2.

![Fig. 2. Block Diagram of a Servomechanism](image)

From the equations and the block diagram it is clear that, the transfer function from the input \( (V_a(s)) \) to the output \( (\theta_m(s)) \) results in a third order system and can be given as follows:

\[ G(s) = \frac{K}{s^3 + as^2 + bs + c} \]  

(14)

To obtain a valid mathematical model, the real data are taken from the motor to employ them in the system identification toolbox of the MATLAB. The inputs applied to the motor and the output of the motor can be seen in the figure 3.

Using the data shown in figure 3, and with the priori of the order of the model, the parameters given in (14), i.e. K, a, b and c are obtained, and they are used to determine the initial ranges for the GA. These obtained parameter values are shown in the Table I.

Also, the parameters for GA are shown in Table II. In this table, the population size is the number of candidates, crossover
fraction is the factor for reproduction, mutation is selected as constraint dependent, the nonlinear constraint is the penalty factor and iteration is the number of iterations.

\[
G(s) = \frac{11520.33}{s^3 + 449.371s^2 + 4103.139s + 11599.107} \quad (15)
\]

To show the validity of the model, the model output and the actual motor output is compared in figure 4.

As the last, the obtained motor parameters from the GA is shown in the Table III.

\[
\begin{array}{|c|c|}
\hline
\text{Parameter} & \text{Value} \\
\hline
\text{K} & 11520.33 \\
\text{a} & 449.371 \\
\text{b} & 4103.133 \\
\text{c} & 11597.107 \\
\hline
\end{array}
\]

In other words, the transfer function of the servomechanism given in (14) can be written as follows:

\[
G(s) = \frac{11820.461}{s^3 + 532.478s^2 + 4786.245s + 11816.266} \quad (15)
\]
In the block diagram, the reference input is the angular position input produced by the master operator, C(s) is the proportional controller, the values of which will be calculated in the next subsection, and \( L_1 \) and \( L_2 \) is the propagation delay from master to slave operator and vice versa respectively, along with \( G(s) \) is the obtained transfer function of the servomechanism.

Supposing that the propagation delay from master to slave is \( L_1 \) seconds and from slave to master is \( L_2 \) seconds, the closed-loop transfer function, \( P_c(s) \) becomes as follows:

\[
P_c(s) = \frac{11520.33e^{-L_1s}}{s^3 + 449.371s^2 + 4103.139s + 11599.107 + 11520.33e^{-L_2s}}
\]

### B. Calculation of All Time-Delay Independent Stabilizing Gains

In this subsection, based on the mathematical model given in (16), all the stabilizing gains providing time-delay independent stability will be computed using the methodology summarized in the subsection II-A.

To begin with, it is noticeable to mention that, the polynomials \( N(s) \) and \( D(s) \) given in (1) are as follows in (16):

\[
N(s) = 11520.33
\]

\[
D(s) = s^3 + 449.371s^2 + 4103.139s + 11599.107
\]

along with a time-delay of \( L=L_1+L_2 \) seconds.

To compute all the time-delay independent stabilizing gains, if the polynomial is formed as suggested in (5), the following is obtained:

\[
W(\omega^2) = \omega^4 + 193728\omega^2 + 6411145\omega^2 + 134539283 - 132718003\omega^2 = 0
\]

If the transformations given in (6)-(7) is done, the polynomials \( A(\nu) \) and \( B(\nu) \) is found as follows:

\[
A(\nu) = \nu^3 + 193728\nu + 6411145\nu + 134539283
\]

\[
B(\nu) = 132718003
\]

Considering these new polynomials and variables in (19) and dividing the both sides by \( A(\nu) \) gives the following root locus problem:

\[
1 - \alpha\nu^3 + 193728\nu^2 + 6411145\nu + 134539283 = 0
\]

![Fig. 7. The root locus of (22) (complete)](image-url)
The corresponding root locus is sketched via MATLAB, and can be seen in figure 7. The initial roots of the locus can be found as $v_1 = -193694.92$ and $v_{2,3} = -16.548 \pm 20.513j$. Since the initial roots are extremely far from each other, the zoomed in version of the root locus can be seen in figure 8.

To interpret the root locus, it is clear from the figures that, there is no positive real roots for $\alpha = 0$. When $\alpha$ begins to increase, the complex conjugate roots break into the real axis, and one of them moves to positive real axis by passing the point $v=0$ for a critical value of $\alpha$, say $\alpha_{cr}$. For $\alpha$ values greater than $\alpha_{cr}$, the corresponding root always locate at the positive real axis, thereby, there exists always a positive root on the real axis. Then it can be summarized that there is no positive root of (22) for the $\alpha$ values such that $\forall \alpha \in (0, \alpha_{cr})$.

In order to compute the $\alpha_{cr}$, if the corresponding $\alpha$ is found at the point $v=0$ using the root locus arguments, the following is computed:

$$1 - \alpha \frac{132718003}{v^3 + 193728v^2 + 6411145v + 134539283} = 0$$

(23)

The critical $\alpha$, i.e. $\alpha_{cr}$ is found as 1.0137. Then it can be concluded that (22) has no positive real roots for $\forall \alpha \in (0, 1.0137)$.

To obtain the corresponding $k_p$ values, if $\alpha$ is retransformed into $k_p$ using (9) gives the $k_p$ set:

$$k_p \in (-1.0068, 0) \cup (0, 1.0068)$$

(24)

Obviously, for these gains the stability of the closed-loop time-delay system is independent of time-delay, i.e. the stability of the time-delay system is identical of the delay-free one. Then all need is to check whether the delay-free system is stable for those $k_p$ values. Computation of the stabilizing gains of $P_c(s)$ given in (16) for $L=0$ is straightforward and can be found as follows:

$$-1.0068 < k_p < 159.0434$$

(25)

It is clear from (25) that for the gain values given in (24), the delay-free system is stable. Therefore, it can be concluded that for gain values given in (24) the time-delay system given in (16) is stable, regardless the value of the time-delay.

**IV. SIMULATION – THE REAL SYSTEM RESULTS**

In this section, for the gain values given in (24), the responses of the slave operator to the signals produced by master operator are obtained under different scenarios, i.e. under different values of propagation delays. From both simulations and the real system responses, it can be observed that the system is stable and the real system results are in accordance with the simulation ones.

In addition, for the gain values outside of the given region in (24), it is also shown that the stability of the system is not independent of the time-delay and the system can be unstable for smaller propagation delays.

To overcome the intrinsic steady state error problem, a pre-amplifier is put after the input signal. The utilized simple block
diagram in both simulations and for the real system is shown in figure 9.

Here, the $K^*$ is the gain of the pre-amplifier the value of which is the inverse of the steady state value of the system. Using the gain set given in (24), with a priori of possessing a stable closed-loop system in (16), the gain of the preamplifier can be computed via final value theorem as follows:

$$K^* = \lim_{s \to 0} \frac{1}{T(s)} = 1 + \frac{11599.107}{11520.33k_p}$$  \hspace{1cm} (26)

At first, the controller value, i.e. $k_p$ is taken as 0.5 and the simulation-real system results under different propagation delays are shown in figures 10-11. From the figures, it is clear that the system remains stable even if the total propagation delay is 12 seconds.

After that, the $k_p$ is selected as 0.85, more close to the borders of the $k_p$ set given in (24). In this case, the system remains stable even under the total propagation delay of 12 seconds. The simulation-real system results are shown in the figures 12-13.

As the last, the $k_p$ is selected as 1.05, which is in the close proximity of the given set in (24), but out of borders. Although the selected $k_p$ is very close to the borders of the set, it is clear from the simulation-real system results that, the robust stability is no longer guaranteed, i.e. the system is unstable, although the total propagation delay is 4 seconds. The results can be seen in figures 14-15.
In this paper a servomechanism subject to teleoperation is considered. The teleoperation can possess huge time-delays and these delays may vary operation to operation, which makes developing efficient control strategies extremely difficult. Since the stability is the first and the foremost important criterion for all of the control systems, the robust stabilization of such servomechanisms with respect to huge and varying time-delays is taken account. To achieve this goal, an efficient method in the literature is employed, and such kind of a mechanism is robustly stabilized in both simulations and in a real environment.

Since the interested controller is P type only, the robust stabilization problem is the only focused one in this paper. Along with the robust stabilization problem, the other performance criteria are planned to be taken into account employing more complicated controller structures such as PD and lead/lag in the possible future publications.

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Balance Control System Application for On-Vehicle Mobile Crane

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Abstract—In this study, a momentum control system is developed with microcontroller to help the vehicle operators safely utilize on-vehicle mobile crane. Balance measures like boom angle and the pressure on cylinder are controlled with a microcontroller and crane control is regulated depending on the previously recorded limits on microcontroller. Developed system aims to minimize operator originated accidents and provides solution to ensure work safety sanctions.

Keywords—Overturn, momentum control system, balance control system, vehicle-mounted mobile cranes

I. INTRODUCTION

Systematic and scientific studies done in order to avoid the conditions which can be harmful for health includes labor and worker safety [1]. In this context, on-vehicle mobile cranes used in heavy work conditions are considered extreme hazardous class in occupational safety and health. Accidents mostly occur while operator is using the crane. Accidents like crane overturn and load drop endangers both labor and worker safety. Figure 1 shows possible outcomes of such an accident.

A force’s ability of turning effect about a point or axis is called momentum. This effect causes cranes to overturn depending on the load pressure on vehicle. System which keeps this effect in safe area by determining load position to vehicle is called momentum control systems. Lately, many studies are conducted to prevent risks and control dangerous situation while operation cranes because of law regulations like occupational health and safety [3]. Studies for important conditions to be considered are investigated while selecting position sensors are analyzed to select sensors for the control system [4]. The system provides a flexible control with feedback which regulates the swings formed because of pressure on boom control cylinder hydraulics with respect to it angle then cranes with and without this control system are compared [5]. An electronic control system is designed and tested in the light of previous studies and according to present conditions-needs to help crane operators operate the crane in safety movement boundaries. In addition, this safety system is a must by the law because of the European Standards.

II. MATERIAL METHOD

This study consists of the input that feeds the control unit and the output generated in accordance with these inputs. With the help of LCD on the control unit, crane operator can see the angle and pressure readings. There is a bypass button for critical situations, a USB jack for serial communication with computers and an emergency button to shut down the system is available on the control unit. Designed control unit is shown in Figure 2.

Figure 1. Mobile Crane Accident [2]

Figure 2. Control Unit
The control unit is designed with 18F4550 microcontroller. This microcontroller reads the angle sensors, pressure sensors and sensors on remote control. In accordance with these inputs, it turns the valves on and off. Microcontroller runs a program which is programmed with Proton Basic programming language. For recording the critical angle and pressure value, an external 24C256 EEPROM is used. This EEPROM keeps the data even if power is cut and thus it is used as a permanent memory.

Since the microcontroller doesn’t have enough input ports for the control system, an CD4067 integrated circuit is used. 32 inputs of CD4067 are controlled by 0,1,2,3, pins of PortA and and outputs of integrated circuit is read form 4., 5. pins of PortA. By this way, only 6 pins of microcontroller are used.

ULN2803 integrated circuit has 8 Darlington transistors. These Darlington transistors are formed with 2 NPN transistors. This integrated circuit transfers the data from remote control valves, buttons and hoist switches to CD4067 integrated circuit inputs. Circuit is fed with 12 V battery because Lm2576T-5 step-down switching regulator, sensors over the crane and valves operate with 12 V. Other integrated circuits like TTL and CMOS operate with +5V. A power module is designed to convert +12V TO +5V and its scheme can be seen at Figure 3. This circuit can convert input voltages in between 7 – 40V to 5V.

Pressure and angle sensors provide analog outputs between 4mA and 20mA. These are converted to voltages between 200mV and 1V with help of a 50ohm resistor connected to their output. This voltage is amplified by factor of 5 using an INA122 instrumentation amplifier to voltages between 1V and 5V. These outputs then read by ADC ports of Pic18F4550 microcontroller and turned into numerical values for angle and pressure. 5 integrated circuits are used as shown in Figure 4.

A desktop application is written in C# programming language for computers. Prepared application is shown in Figure 5.
This software provides an interface for the crane manufacturer, to create a safe movement area for the crane mechanism depending on the mechanical technical properties and capacity and to upload this information to microcontroller. Depending on the cranes current angle positions (Angle1, Angle2) and the pressure values on boom cylinder (Pressure1, Pressure2, Pressure3) are calculated as maximum limit values and sent to Pic18F4550 microcontroller over USB port. In addition, these values are stored in a database to be uploaded to other control units for same type of cranes with the aim of saving time.

III. RESULTS AND CONCLUSIONS

In this study, minimization of operator originated accidents for on-vehicle mobile cranes aimed and tested. In testing phase, the intended and unintended mistakes an operator could do are prevented by the control system and the operator warned both vocally and visually. Inadequate number of input pins of 18F4550 is compensated using CD4067 multiplexer integrated circuit thus system stability and reliability is improved via including necessary information (angle, pressure, boom status, direction of rotation, oil temperature, etc.) provided successful results for this study and future studies. Materials used in this study are easily accessible, so that the momentum control system can be developed and produced in our country. This study shows that, outrigger legs of the mobile crane which stabilizes it, should be included in calculations by determining the expanded length of the legs and adjusting the safe movement areas according to it.

REFERENCES

Tuning of Discrete PID Controllers Using Dominant Pole Placement Approach for Time-Delay Systems of Any Order

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Abstract—In this paper, a simple methodology is proposed based on the dominant pole placement approach for arbitrary order time-delay systems. Discretization of such systems to avoid the formidableness of the infinite number of poles, and applying the strategy proposed in this paper, a pair of the closed loop poles can be assigned to the desired locations, whereas the remaining ones are guaranteed to be located inside a disc with the predetermined radius in the z-domain. To prove the validity of the method, the proposed algorithm is applied to a servomechanism in a real environment; whose approximate model is derived as a second order system with time-delay with the help of system identification toolbox of the MATLAB. Then it is shown that the proposed controller values satisfy the desired performance criteria; and the actual response of the system is in accordance with the theoretical one.

Keywords—Discrete Control Systems, Time-Delay Systems, PID Controllers, Dominant Pole Placement.

I. INTRODUCTION

Time-delay, which is almost an inevitable phenomenon for most of the physical systems, can be loosely defined as the amount of time elapsed until the effects of the input signal can be observed at the output. Although time-delay has some positive effects on a system, generally speaking, it has adverse effects on any kinds of systems [1].

From the mathematical point of view, for Linear Time Invariant (LTI) and Single Input Single Output (SISO) systems, this adverse effect is mostly caused by the fact that the time-delay term brings infinitely many poles to the closed-loop system in the s-plane. As might be expected, dealing with such a situation becomes extremely difficult; either at analysis or at synthesis level.

Moreover, this fact also makes the straightforward stability checks almost impossible for such kind of systems. As another result, not only the analysis-synthesis tasks but also determination of the stability is much more complicated than the delay-free systems. This can be evidenced by the proposed stability methods available in the literature [2]-[3].

Since the first and the foremost important criterion for a controller is to stabilize the system, computation of all stabilizing controllers is important for much of the control tasks. This brings many advantages to the designers such as avoiding recurring stability checks when the performance criteria of the system need to be changed, which may be extremely time consuming especially for time-delay systems. Again, as an expected result, computation of all stabilizing controllers in the controller parameter space is not an easy task for time-delay systems [4]-[7].

However, in most of the control systems, only the stability itself is not sufficient. Therefore, computation of all stabilizing controller set meeting the desired performance criteria (such as overshoot, settling time, etc.) is meaningful; which can be thought as a proper subset of all stabilizing controller set.

Apparently, one of the most popular methods to accomplish this requirement is the dominant pole placement. However, as stated before, since the time-delay systems have infinitely many poles in the closed-loop, such an achievement is extremely difficult, especially for PID type low-order controllers with limited parameters. On the other hand, the PID controller and its variants have been still the leading utilized controller form in industry up to 95% [8]. Due to the popularity of this control structure, there are some methods available in the literature about the dominant pole placement with PID controllers for time-delay systems [9]-[11].

An important strategy to circumvent this difficulty might be digitizing the system. Since the equivalent transfer function in the z-plane no longer possess infinitely many poles; instead it begins to possess additional finite number of poles at \( z = 0 \), the number of which is a function of the sampling time. As
might be expected, such a situation facilitates the dominant pole placement process [12]-[13].

Based on the strategy defined above, a digitized PID design providing dominant pole placement for time-delay systems in the z-plane is proposed in this paper. Apparently, the given system is digitized and its transfer function is expressed in the z-domain. Then based on the performance criteria, the location of the dominant poles is computed. After that all the controller set for which the closed-loop system possess a pole pair at the desired location, is computed in terms of the $K_p$ parameter. In order to provide the remaining roots to locate in a disc with a predetermined radius, the Nyquist method is employed. To verify the proposed methodology, the method is applied to a servomechanism in the real environment. Since the employed motor parameters are not explicitly known, the continuous transfer function of the servomechanism is obtained via MATLAB system identification toolbox as a second order system in the s-plane.

It is worth noting that, the predetermined radius plays a key role for the system to behave as desired. In general, it can be said that, the smaller the radius, the greater the performance. However, when the radius is selected too small, the resulting controller set may result in an empty set. Therefore, based on an numerical calculations, the minimum achievable length of the radius is also obtained graphically in this paper.

The paper is organized as follows: In the second section, the complete methodology is expressed in two steps. In the first one, it is mentioned how the controller parameters are obtained in terms of $K_p$ in order for the characteristic expression to comprise the desired dominant roots. In the second one, using the Nyquist criterion, the required range of $K_p$ is calculated in order for the non-dominant roots to be placed in the disc with the predetermined radius. In the third section, the method is applied to a servomechanism in the real environment. To apply the method, the transfer function of the system is obtained as a second order one in the s-plane, employing the system identification toolbox of the MATLAB. Moreover, all $K_p$ values are computed and plotted for each value of the predetermined radius in the $K_p - r$ plane. From that plot, the minimum achievable radius length, i.e. the maximum dominance factor of the dominant poles can be easily determined.

II. DISCRETE PID CONTROLLER DESIGN

A. Calculation of the PID Controller Parameter Set to Assign the Dominant Pole Pair

A discrete-time transfer function of a system in general form can be given as follows.

$$G(z) = \frac{N_c(z)}{D_c(z)}$$  \hspace{1cm} (1)

The PID controller in discrete-time domain can also be given as follows.

$$F(z) = \frac{N_F(z)}{D_F(z)} = \frac{(K_p+K_i+K_d)\omega^2 - (K_p+2K_d)\omega + K_d}{z(z-1)}$$  \hspace{1cm} (2)

The characteristic equation of the closed-loop system with unity feedback is expressed as below.

$$P_c(z) = D_F(z)D_c(z) + N_F(z)N_c(z) = 0$$  \hspace{1cm} (3)

Here, it is aimed the dominant pole pair to be assigned to the points $z_{1,2} = \sigma \pm j\omega$ in z-plane using a PID controller. It is clear that the closed-loop characteristic equation should be satisfied by the dominant poles; therefore, (3) can be written as below.

$$D_F(\sigma + j\omega)D_c(\sigma + j\omega) + N_F(\sigma + j\omega)N_c(\sigma + j\omega) = 0$$  \hspace{1cm} (4)

The equation given above can be solved by equating its real and imaginary parts to zero,

$$\begin{align*}
(D_{F1m}D_{c1m} - D_{FRe}D_{cRe}) + (N_{F1m}N_{c1m} - N_{FRe}N_{cRe}) &= 0 \\
(D_{FRe}D_{c1m} + D_{F1m}D_{cRe}) + (N_{FRe}N_{c1m} + N_{F1m}N_{cRe}) &= 0
\end{align*}$$  \hspace{1cm} (5)\hspace{1cm} (6)

where

$$D_{F1m} = Im[D_F(\sigma + j\omega)], \quad D_{FRe} = Re[D_F(\sigma + j\omega)]$$

$$D_{c1m} = Im[D_c(\sigma + j\omega)], \quad D_{cRe} = Re[D_c(\sigma + j\omega)]$$

$$N_{F1m} = Im[N_F(\sigma + j\omega)], \quad N_{FRe} = Re[N_F(\sigma + j\omega)]$$

$$N_{c1m} = Im[N_c(\sigma + j\omega)], \quad N_{cRe} = Re[N_c(\sigma + j\omega)]$$

It can easily be seen that in (5) and (6), only the expressions $N_{FRe}$ and $N_{F1m}$ consist of unknown parameters (PID controller parameters); therefore, if $N_{FRe}$ and $N_{F1m}$ is solved, it is possible to obtain,

$$N_{FRe} = -\frac{N_{c1m}Y - N_{cRe}X}{Z}$$  \hspace{1cm} (7)

$$N_{F1m} = -\frac{N_{c1m}X + N_{cRe}Y}{Z}$$  \hspace{1cm} (8)

where $X$, $Y$ and $Z$ defined as follows to avoid complexity.

$$X = D_{F1m}D_{c1m} - D_{FRe}D_{cRe}$$

$$Y = D_{FRe}D_{c1m} + D_{F1m}D_{cRe}$$

$$Z = N_{c1m}^2 + N_{cRe}^2$$

Note that, it is possible to obtain following expressions for a discrete PID controller,

$$N_{FRe} = K_d(\left(-\left(1+\sigma^2\right)\omega^2\right) + K_p(\left(-\sigma + \sigma^2 - \omega^2\right) + K_d\left(\sigma^2 - \omega^2\right)$$  \hspace{1cm} (9)

$$N_{F1m} = K_d\left(2\sigma - 2\right)\omega + K_p\left(2\sigma - 1\right)\omega + K_d\left(2\sigma\omega\right)$$  \hspace{1cm} (10)

Thus, discrete-PID controller parameters $K_i$ and $K_d$ can be obtained in terms of the parameter $K_p$ with the help of the expressions (7) and (8) as below.
\[
\left( \frac{K_d}{K_i} \right) = \frac{1}{\pi} \left( \frac{-1 + \sigma - \omega^2}{a^2 + \omega^2} \right) \left( \frac{N_{G_{in} x + N_{G_{ex} y}}}{z} \right) - \frac{1}{\pi} \left( \frac{\frac{1}{\sigma} - \omega^2}{a^2 + \omega^2} \right) K_p^2
\]

where,
\[
\Delta = -2\omega (-\sigma + \sigma^2 + \omega^2)
\]

As a result, the discrete-PID controller parameter set, which assigns dominant poles to the points of \( z_{1,2} = \sigma \pm j\omega \) in \( z \)-plane, is obtained in following form.
\[
S := \{ F(K_i(K_p), K_d(K_p), K_p) \mid \forall K_p \in \mathbb{R} \} \quad (12)
\]

This set defines a line in \( (K_p, K_d, K_i) \) 3-dimensional parameter space. On the other hand, it should be considered that the controller set given in (12) assigns dominant poles to the points of \( z_{1,2} = \sigma \pm j\omega \); however, the remaining poles can be located anywhere (including unstable region) in \( z \)-plane depending on the parameter \( K_p \). Calculation of the subset of PID controller parameter set, which assigns the remaining poles in a disc of radius \("r"\) in \( z \)-plane, is explained in the next section.

### B. Calculation of the Subset to Assign Remaining Poles

After obtaining the expressions of PID controller parameters \( K_i \) and \( K_d \) in terms of the parameter \( K_p \), those parameters can be replaced in the closed-loop characteristic polynomial. Thus, the closed-loop characteristic polynomial only depends on the parameter \( K_p \). In addition, it is clear that this characteristic equation also comprises the dominant pole pair; therefore, following equation can be written.

\[
P_c(z, K_p) = (z^2 - 2\sigma z + \sigma^2 + \omega^2) P_e(z, K_p)
\]

Here, the polynomial \( P_c(z, K_p) \) is constructed by the unassigned closed-loop poles. It is desired the roots of polynomial \( P_e(z, K_p) \) to be located in a disc with radius \( r^m \) in \( z \)-plane where \( r = \sqrt{\sigma^2 + \omega^2} \) and \( m \) is defined as dominance factor. If the corresponding \( K_p \) interval is found, then it is possible to obtain a subset of the PID parameter set obtained earlier such that dominant pole placement is carried out successfully, as given below.

\[
\tilde{S} := \{ F(K_i(K_p), K_d(K_p), K_p) \mid \forall K_p \in (k_p^-, k_p^+) \} \subset S
\]

The problem, which is stated as the roots of polynomial \( P_c(z, K_p) \) to be located in a disc of radius \( r^m \) in \( z \)-plane, can be converted to the stability problem of the polynomial \( \tilde{P}_e(z, K_p) = P_e(r^m z, K_p) \). In order to solve this problem, there are several methods such as Jury test, Routh-Hurwitz criterion with the help of bilinear transformation. However, as the order of closed-loop system is increased, the inequalities (probably nonlinear) obtained from Jury or Routh table may become very complex to reduce. For this reason, in this study, the interval of stabilizing \( K_p \) gain is calculated with the help of Nyquist theorem by reconstructing the polynomial \( \tilde{P}_e(z, K_p) \) as follows.

\[
1 + K_p \tilde{G}(z) = 0
\]

In the Nyquist stability analysis, it is desired to find the gain interval in which the number of unstable closed-loop poles (\( Z \)) is zero with the help of the number of unstable poles (\( P \)) of open-loop system and the number of encirclements (\( N \)) of the Nyquist plot around a critical point.

\[
N = Z - P
\]

Here, the number of unstable poles of \( \tilde{G}(z) \) and thus the number of encirclements required of Nyquist plot can be calculated. After that, desired \( K_p \) interval that satisfies the required number of encirclements can be found.

Note that, it is not always possible to provide dominant pole placement because \( \tilde{S} = \emptyset \) can be found after the calculations. This means that there is not any PID controller which satisfies the desired performance criteria and dominance factor in the closed-loop.

### III. Simulation and Implementation Results

In this section, proposed discrete-PID controller design is applied to the position control problem of a DC motor and success of the proposed method is firstly demonstrated on simulation environment in MATLAB and then on real environment. The DC motor system [14] to be controlled is illustrated in Figure 1. Due to the fact that motor parameters are unknown, open-loop transfer function is obtained with the help of system identification toolbox of MATLAB.

![Fig. 1. DC motor system to be controlled.](image)
As a result, the open-loop transfer function of the DC motor system is given as below.

\[ G(s) = \frac{36.64}{s^2 + 15.6s + 36.62} e^{-0.2s} \]

Discrete transfer function of the system with the sampling time of \( T = 0.05 \) seconds is found as follows.

\[ G(z) = \frac{0.027487 + 0.035636z}{z^2 + 1.39532z - 0.45841} z^{-4} \]

In the closed-loop, it is desired transient response of the system to satisfy 5% overshoot and 2 seconds settling time. Corresponding dominant pole pair in \( z \)-plane is then given as below.

\[ z_{1,2} = \sigma \pm j\omega = 0.9 \pm j0.0947 \]

It is now possible to obtain the discrete-PID controller parameters \( K_i \) and \( K_d \), which assign dominant poles to the desired locations in the closed-loop, in terms of the parameter \( K_p \) using the expression (11) as follows.

\[ K_i = 0.02833 + 0.1171 K_p \]
\[ K_d = -2.3815 + 5.0454 K_p \]

If those parameters are replaced in closed-loop characteristic polynomial and written in the form given with (13),

\[ P_c(z, K_p) = (z^2 - 1.7997z + 0.81873) P_e(z, K_p) \]

where \( P_e(z, K_p) = z^6 - 0.59558z^5 - 0.0369z^4 - 0.0372z^3 - 0.036726z^2 + (0.2196K_p - 0.1195)z + (0.1694K_p - 0.07996) \)

Let the remaining (unassigned) poles to be 4 times away from the dominant pole pair in \( z \)-plane (i.e. in a disc with radius \( r = 0.67 \)). First of all, it is required to obtain the polynomial \( \bar{P}_e(z, K_p) = P_e(r^m z, K_p) \) in order to convert the problem to the stability problem.

\[ \bar{P}_e(z, K_p) = 0.090727z^6 - 0.08065z^5 - 0.00745z^4 - 0.0112z^3 - 0.0165z^2 + (0.147K_p - 0.08)z + (0.1694K_p - 0.07996) \]

After that, the obtained polynomial should be rearranged as given in (15) to be able to draw Nyquist plot. If the required calculations are done, Nyquist plot of the transfer function \( G(z) \) is drawn as in Figure 3.

Since the open-loop system has \( P = 3 \) unstable poles, the number of required encirclements is \( N = -3 \) for the stability of the polynomial \( \bar{P}_e(z, K_p) \). The tight interval, which satisfies the desired number of encirclements, can be seen from the Nyquist plot. If required calculations are carried out, intersection points of Nyquist plot and real axis and thus interval of the \( K_p \) is found as below.

\[ K_p \in \left( \frac{-1}{-1.7104}, \frac{-1}{-0.56426} \right) = (0.58466, 0.63928) \]

On the other hand, if the dominance factor (m) is left as a free parameter instead of assigning a value, a polynomial with 2 free parameters is obtained. If one of the stability tests is applied such as Jury test directly (or by gridding one of the parameter if higher order system is under consideration), the resulting inequalities define a region in \( K_p - m \) plane. Thus, the smallest radius in which unassigned poles can be located is found. Figure 4 shows this region for the considered DC motor example.
As a result, the PID controller set which assigns dominant poles to the desired points and keeps remaining poles inside a disc of radius $r = 0.67$ is found. For instance, if $K_p = 0.63$ is selected from the interval,

$$K_i = 0.1021$$
$$K_d = 0.7971$$

and the discrete-PID controller transfer function

$$F(z) = \frac{0.7971 - 2.2242z + 1.5292z^2}{z (z - 1)}$$

is obtained. Pole-zero map of the closed-loop system with proposed controller is given in Figure 5. It is seen from the figure that all poles, except dominant pole pair, are located in desired region.

![Fig. 5. Pole-zero map of the closed-loop system.](image)

Designed PID controller is firstly applied to the system model in simulation environment and then applied to the DC motor system. Resulting closed-loop step responses are shown in Figure 6 together.

![Fig. 6. Closed-loop responses in simulation and real environment.](image)

It can be seen from the figure that the settling time of DC motor in the closed-loop is around 2 seconds which is equal to the desired value and the overshoot is around 6% which is very close to the desired performance specification. The value of the overshoot is found to be slightly different because one of the closed-loop zeros are located relatively close to the dominant pole pair.

IV. CONCLUSIONS

In this study, discrete-PID controller set, which assigns dominant poles to the desired locations in $z$-plane and keeps remaining poles away from the dominant pole pair to guarantee a chosen dominance factor, is found. Controller design method is firstly explained and then demonstrated on DC motor example. It is shown that with the designed discrete-PID controller, non-dominant poles are located inside a disc with chosen radius whereas the dominant poles are assigned to the pre-determined locations in order to satisfy desired transient response. Furthermore, it is also shown that the resulting transient response of the DC motor is very close to the desired response in the closed-loop. Thus, success of the proposed PID controller design method is verified.

Proposed design method is carried out through the closed-loop system poles; however, closed-loop zeros, which are located in the dominant region, can also affect the transient response. This can be stated as the only drawback of the proposed method. It is planned future work to include consideration of the effects of closed-loop zeros during the controller design.

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Design and Implementation of a Microcontroller Controlled Digital Mahya

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Abstract— Mahya is a string of lightened inscriptions set up between two minarets of mosques during Ramadan nights. In this study, a microcontroller controlled digital mahya which can be programmed with a remote control was designed using digital fonts. Two counts of Pic16F877A microcontroller were employed; one on the mainboard and the other in the remote control. Moreover, one Pic12F675 microcontroller was used for each letter on the mahya. The software installed on the microcontrollers was prepared using the PicBasicPro language. 3 counts of different texts can be stored in the remote control module of the mahya and the desired text on the mahya is sent from the remote control to mahya via serial communication. The mahya designed for this study is made up of 30 digital letters and each letter consists of 14 segments. All letter segments are pre-written using the PicBASIC PRO program. Printed circuits were prepared in a workshop setting and then it was started setting up between the minarets of a mosque.

Keywords— Include at least 5 keywords or phrases

I. INTRODUCTION
Mahya is the lightened inscriptions hung between the minarets of double-minaret mosques during the Ramadan month. It has two meanings in Arabic; ‘life’ and ‘monthly’. The main goal of setting up mahyas is to give nice messages to people and lead them to good deeds and benevolence. In the early periods, mahyas were used to be set up with oil candles strung over the ropes. Today, mahya and the art of mahya is the lightened inscriptions hung between the minarets of double-minaret mosques during Ramadan nights. In this study, a microcontroller controlled digital mahya which can be programmed with a remote control was designed using digital fonts. Two counts of Pic16F877A microcontroller were employed; one on the mainboard and the other in the remote control. Moreover, one Pic12F675 microcontroller was used for each letter on the mahya. The software installed on the microcontrollers was prepared using the PicBasicPro language. 3 counts of different texts can be stored in the remote control module of the mahya and the desired text on the mahya is sent from the remote control to mahya via serial communication. The mahya designed for this study is made up of 30 digital letters and each letter consists of 14 segments. All letter segments are pre-written using the PicBASIC PRO program. Printed circuits were prepared in a workshop setting and then it was started setting up between the minarets of a mosque.

II. MATERIAL AND METHOD

In the Microcontroller Controlled Digital Mahya implemented, the software inside the microcontroller was written using the PICBASIC PRO program. Printed circuits were prepared using the ARES printed circuit program that comes inside the Proteus Professional software pack. Moreover, before circuits were passed to printed circuit, microcontroller codes and working principles of integrated circuits were tested in the ISIS Professional[5] which is an electronic simulation program. Printed circuits were prepared in a workshop setting using the ironing method at the testing stage. After successful results were obtained at the testing stage, printed circuits for serial production were prepared by firms that could do this job professionally.

2.1 Serial Communication Technique
Serial communication technique is preferred for the purpose of reducing complexity, lowering the cost and enabling the ease of control in the businesses, automation systems and factories with many motors and machines. It also has advantages such as programming the system upon request, not needing to install additional data line for the subsequently added devices to circuit. Serial communication has a broad range of usage in today’s world. The communication in the computer devices like modem, printer, floppy, hard disk, optical drives and the communication between the microprocessors are conducted in a serial form. In addition to these, serial form communication is also used in the cases where it is targeted to reduce the number of line [5-8].

Serial Communication Software; Pic Basic Pro commands enabling serial communication are as follows:

Data sending command:
SEROUT2 VERIOUT,188,["S","U",DATA1]
This command transmits data at 4800 baud rate. It transmits the letters “S” and “U” before sending BITLER1 data.

Data receiving command:
SERIN2 VERIIN,188,100,ATLA,[WAIT ("SU"),DATA1]
This command reads the data sent at 4800 baud rate and transfers the data coming after the regularly sent letters “S” and “U” to BITLER1 variable[5].

2.2. Structure of the Implemented System...
The system we designed basically consists of three modules. The circuit formed for our first module is the ‘Main Board’ section which sends via serial communication the letter information that has to appear in displays and it is put together on the minaret with displays. The second one is the display module that shows letters. Pic12f675 microcontroller was used for each letter in this module. This microcontroller sends data that come from the main board via serial communication to 74HC595 integrated circuit which drives the segments of the display. The third module consists of remote control system. The user prepares the text that he wants to show on the mahya using this remote control system and transmits these data to mainboard through serial communication. Figure 1 shows the structure of the designed system.

![Figure 1 - Mahya Block Diagram](image1)

### 2.2.1 Mainboard Module
This module ensures the control of the designed system. It sends and receives data using serial communication technique via both the display module and the Keypad Module. A Pic16F877A microcontroller was used for this module. Data programmed by the user in the Keypad module are read through serial communication and saved to internal EEPROM of the 16F877A microcontroller. It sends the necessary data to display module for the the user-programmed text to appear in displays.

### 2.2.2 Control Module
This module helps to program the inscription that is to be shown in the mahya. It has a 16F877A microcontroller, a keypad with 16 buttons and an LCD display.

### 2.2.2.1 Pic16F877A Mikrodenetleyicisi
As in the mainboard module, a 16F877A microcontroller was used in the control module too. This microcontroller reads the data coming from the keypad module and these data are shown in the LCD display. After being programmed in the control module, the text which is to be shown in the displays is sent to the mainboard module through serial communication. The software installed to this microcontroller was written using the PicBasicPro programming language.

#### 2.2.2.2 Keypad module
This module is composed of 16 buttons and controlled with the 8 ports (PORTD) of the microcontroller. It operates with the same operating logic of cell phone keypads. For instance, the number 2 shows up in the display when first pressed on the key 2, the letter A appears when pressed a second time and B and C in sequence. The user uses this module to be able to program the inscription to be shown on the mahya.

#### 2.2.2.3 LCD Display
A 2x16 LCD display was used in this study. The user takes advantage of this display while programming the mahya. The text that appears on the LCD display is sent to the mahya. 8 ports (PortB) of 16F877A microcontroller was used in order to control the LCD display.

### 2.2.2 Display Module
30 counts of this module were designed since the implemented mahya consisted of 30 letters. Figure-2 shows printed circuit and circuit diagram of the display module.
2.2.1.1 14 Segment Display

A 14 segment display in Figure-4 was prepared to show the characters of the text made up for the mahya. 2 segments were added so as to show Turkish characters. One of these segments was placed over the letter and the other one beneath the letter. Strip leds were used to light these segments.

2.2.1.2 12F675 Microcontroller

This microcontroller receives data coming from the mainboard through serial communication and then send these data to 74HC595 integrated circuits so that the letters can appear on displays. It has 8 pins and 6 I/O ports. The software written for this microcontroller checks whether data coming from the mainboard module through serial communication belongs to itself or not. If the data belongs to itself, it also reads the rest of the data and transmits it to 74HC595 integrated circuit. Because output ports of 74HC595 integrated circuit are connected with Display segments, the requested letters show up in display.

2.2.1.3 74HC595 integrated circuit

This is an 8 bit shift register integrated circuit. It reads data coming from 12F675 microcontroller through SPI serial communication protocol and images these data at its 8 output (QA-QH) [9]. 2 counts of this integrated circuit were used for each letter.

III. CONCLUSIONS AND RECOMMENDATION

Electronic components of a Mahya stretched between the minarets of mosques during the Ramadan months were created and described in this study. The most important difference between the implemented mahya and today’s mahyas is that it was designed using digital fonts and that it enabled to program desired inscriptions with a remote control. Thus instead of showing only one text, it can show different texts on different days throughout the Ramadan month between two minarets. The circuits designed for the mahya were tested in a workshop setting. After hardware and software problems that occurred during the testing stage were resolved, the system was put into use with its final version. A view of the implemented mahya can be seen in Figure-5. The results of tests showed the employability of digital mahya.

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AN OFF-LINE SIMULATION TOOL FOR PUMA ROBOT USING UNITY 3D

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Abstract—This paper presents an off-line simulation tool for PUMA robot manipulator which is commonly used various purposes such as material handling, welding and surgery. This new tool using UNITY game engine software provides powerful real-time simulation and verification of robot manipulator designs. PUROLAB allows users to design his/her own virtual robot laboratory including objects and conveyer systems and test the real-time systems. PUROLAB has very powerful Graphical User Interface (GUI) that provides users to understand fundamental of robot kinematics easily.

Keywords—Robotic Simulation tools, Off-Line Robot Programming, GUI, Robot Test Software

I. INTRODUCTION

Robot programming is one of the main issues of robotics. There are two different programming issues in robotics, namely off-line and on-line programming. Off-line programming is a method of planning, generating, simulating and verifying a robot program at a remote computer. It presents several advantages to operators and designers [1-4]. Some major advantages can be described as follows: i) The robot motion can be designed, modified and simulated before performing in real-time, ii) Off-line programming provides flexibility. Several times a program can be modified without interrupting the robot task, iii) since robot program is prepared away from the robot, the programmer is free of robot accident, iv) it provides fast correction of any error occurred in the robot program.

There have been several robot simulation tools developed until now. Das et al. [5] developed a simulation tool named as RCAAAD (Robot Computer Aided Analysis and Design). It permits designers to analyze and optimize their designs. The Robotics Toolbox for Matlab [5] presents many helpful applications to the users such as such as kinematics, dynamics and trajectory generation. Although it is very useful simulation tool its GUI is very week like RCAAD. Nethery and Spong [7] developed Robotica that includes about 30 functions for kinematics, dynamics and animations of robots. Since Robotica is required set up Mathematica before loading actual program, Robotica does not provide GUI. Nayair [8] developed Robotect that is windows-based graphical user interface robot simulation tool for especially modelling and analyzing manipulator designs. Zlajpah [9] developed a simulation toolbox for redundant planar manipulators only. Zlajpah’s simulation tool does not support GUI. ROBOOP [10] is developed for synthesis and simulation of robot manipulators. Bingul et al. [11] developed RoboSim for modeling, visualization and performance analysis of serial robot manipulators. Turnell et al. [12] presented SimBot for development of autonomous robots. Vollmann [13] developed a simulation tool for KUKA. This simulation tool does not provide any interactive GUI. Alfs et al. [14] developed a simulation tool for designing for advanced robots. Kucuk and Bingul [15] developed a robot simulation toolbox to improve the understanding of robotics fundamentals through interactive GUI. Other simulation tools can be found in [16,17,18,19,20,21]. Table 1 illustrates some important properties simulation tools developed until now.

In this paper, an off-line robot simulation tool is developed for PUMA robot manipulator which is an extensively used in industry for performing several tasks such as material handling, welding and surgery. This new tool is developed by using Unity game engine software that provides very powerful interactive GUI facilities for operators to perform several applications. Unity developed by Unity Technologies [22] is a game engine software that is used for preparing video games, consoles and mobile devices. It provides operators to use real world parameters in their animations. Another advantage of using Unity game engine is to have possibility for designing his/her own GUI without limiting himself/herself traditional custom application forms. High-resolution graphics library of Unity game engine allows operators to use earlier prepared models in any future application. The main advantages of PUROLAB over the other simulation tools given above can be summarized given as follows.

i) PUROLAB is developed by using Unity game engine software that offers very powerful GUI facilities to perform several applications interactively.

ii) PUROLAB provides users to design his/her own virtual robot laboratory including objects and conveyer systems.
In this section, forward kinematics, inverse kinematics and trajectory planning is shortly introduced to provide robotics fundamentals.

### A. Forward kinematics

Forward Kinematics is the first stage to design a new serial robot manipulator. It is a mapping from joint coordinates to Cartesian coordinates and an easy problem for serial robot manipulators. The homogeneous transformation matrix for each joint is derived to compute the forward kinematics. D-H [23] parameters are used for obtaining homogeneous transformation matrix for a joint:

\[
{i-1}{i}{j}\mathbf{T} = \begin{bmatrix}
\cos \theta_i & -\sin \theta_i & 0 & a_i \\
\sin \theta_i \cos \alpha_i & \cos \theta_i \cos \alpha_i & -\sin \alpha_i & -\sin \theta_i \sin \alpha_i \\
\sin \theta_i \sin \alpha_i & \cos \theta_i \sin \alpha_i & \cos \alpha_i & \cos \theta_i \cos \alpha_i \\
0 & 0 & 0 & 1
\end{bmatrix}
\]

Where \( \theta_i \) is the joint angle, \( \alpha_{i-1} \) is the twist angle, \( a_{i-1} \) is the link length, and \( d_i \) is the joint offset. The forward kinematics of the end-effector with respect to the base frame is described as follows:

\[
0_T = {0}_1 T_2 T_3 \ldots
\]

where \( T \) illustrates the transformation matrix of a joint. The forward kinematics can also be expressed as follows:

\[
{T}_n = \begin{bmatrix}
r_{11} & r_{12} & r_{13} & p_x \\
r_{21} & r_{22} & r_{23} & p_y \\
r_{31} & r_{32} & r_{33} & p_z \\
0 & 0 & 0 & 1
\end{bmatrix}
\]

Where \( r_{ij} \) and \( p_p \), \( p_y \), \( p_z \) are the elements of rotation matrix position vector, respectively \( (i = 1, 2, 3) \). For a six jointed robotic manipulator the forward kinematics can be described as follows.

### II. BACKGROUND

In this section, some important robotics simulation tools are described:

<table>
<thead>
<tr>
<th>Program</th>
<th>Visualizing</th>
<th>Programming language</th>
<th>Programming tool</th>
<th>Interactive</th>
</tr>
</thead>
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<td>PUROLAB</td>
<td>Solid/Wire</td>
<td>MATLAB</td>
<td>Mathematica</td>
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<tr>
<td>ROBOLAB</td>
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<td>C++</td>
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<td>RCAAAD</td>
<td>Solid</td>
<td>Wire</td>
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<td>ROBOTICA</td>
<td>Solid</td>
<td>Wire</td>
<td>MATLAB</td>
<td>Yes</td>
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<td>ROBOP</td>
<td>Wire</td>
<td>Wire</td>
<td>CH-b</td>
<td>Yes</td>
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<td>Solid</td>
<td>Wire</td>
<td>Common Lisp</td>
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<tr>
<td>PLANAR</td>
<td>Wire</td>
<td>Wire</td>
<td>Visual C++</td>
<td>Yes</td>
</tr>
<tr>
<td>ROBOOP</td>
<td>Solid</td>
<td>Wire</td>
<td>MATLAB</td>
<td>Yes</td>
</tr>
</tbody>
</table>

iii) PUROLAB allows operators to visualize the fundamental robotic applications like the forward kinematics, inverse kinematics and trajectory planning in more efficient way.

iv) PUROLAB allows operators to change the link parameters of PUMA robot manipulator to see interactively the structure of the solid model.

v) PUROLAB provides operators to enable a better understanding of orientation and positioning in three dimensional spaces.

vi) PUROLAB provides the user to locate the PUMA robot manipulator, conveyor systems and objects in any place in the workspace.
\[ 0^T = 0^T(q_1)0^T(q_2)0^T(q_3)0^T(q_4)0^T(q_5)0^T(q_6) \] (4)

where \( q_i \) is the revolute or prismatic joint variable for \( i^{th} \) joint.

**B. Inverse Kinematics**

Although the forward kinematics is easy problem, the inverse kinematics is difficult and complex problem. The inverse kinematics solution is also computationally expensive. The nonlinearities make the inverse kinematics problem more difficult to solve.

Inverse kinematics problem is a mapping from Cartesian coordinates to joint coordinates. The link transformation matrices are described as below to solve the inverse kinematics \([24]\).

\[ \begin{bmatrix} 0^T \\ 0^T \end{bmatrix} = \begin{bmatrix} 0^T \\ 0^T \end{bmatrix}^{-1} 0^T 1^T 2^T 3^T 4^T 5^T 6^T \] (5)

Since \( \begin{bmatrix} 0^T(q_i) \end{bmatrix}^{-1} \begin{bmatrix} 0^T(q_i) \end{bmatrix} \) equals identity matrix. The above equation simplifies as follows

\[ \begin{bmatrix} 0^T \end{bmatrix}^{-1} 0^T = 1^T 2^T 3^T 4^T 5^T 6^T \] (6)

Where \( 0^T 6^T \) includes the given orientation and position data. The following equations can be derived in a similar way.

\[ \begin{bmatrix} 0^T 1^T 2^T \end{bmatrix}^{-1} 0^T = \frac{1}{2} 3^T 4^T 5^T 6^T \] (7)

\[ \begin{bmatrix} 0^T 1^T 2^T 3^T \end{bmatrix}^{-1} 0^T = \frac{1}{3} 4^T 5^T 6^T \] (8)

\[ \begin{bmatrix} 0^T 1^T 2^T 3^T 4^T \end{bmatrix}^{-1} 0^T = \frac{1}{4} 5^T 6^T \] (9)

\[ \begin{bmatrix} 0^T 1^T 2^T 3^T 4^T 5^T \end{bmatrix}^{-1} 0^T = \frac{1}{5} 6^T \] (10)

Lower dimensional approach \([25]\) presents another important equation to solve inverse kinematics.

\[ 2^T 3^T 4^T 5^T = 2^{-1} 0^T 1^T 0^T 2^T 3^T 4^T 5^T \] (11)

**C. Trajectory Planning**

Trajectory planning is one of the vital issues of robotic manipulators since it is required to execute the desired task with acceptable performance \([26]\). Trajectories must provide smooth motion to provide high tracking accuracy. Rough and jerky motions cause vibration and errors in joints. In general, robot trajectories are first planned off-line and then the end-effector tracks the planned trajectory on-line. There are several trajectory planning algorithms such polynomial \([Craig]\), trigonometric \([27]\), quartic \([28-29]\), B-spline \([30]\) and cubic spline \([31]\) are used in robotics. In this paper a 7th order polynomial is used for trajectory planning.

**III. OVERVIEW OF SIMULATION TOOL**

Some important applications are illustrated for describing the features of PUROLAB in this section. The new simulation tool PUROLAB includes applications of forward kinematics, inverse kinematics and trajectory planning. The mainframe and flowchart of PUROLAB are given Figure 1 and Figure 2, respectively.

![Mainframe of PUROLAB](image1)

**Fig. 1. Mainframe of PUROLAB**

![Flowchart of PUROLAB](image2)

**Fig. 2. Flowchart of PUROLAB**

After clicking “Opens Scene” button, the new window given by Figure 3 appears on the screen. Figure 3 provides user to design kinetic parameters (lengths and radiuses) of his/her own robot, conveyer system and objects. This feature is an important advantage of PUROLAB over other simulation tools.
tools described in Table 1. In this application, link lengths for
PUMA robot manipulator is designed as \( h_1=2 \), \( d_2=4 \), \( l_2=18 \) and \( d_4=14 \) and \( d_6=0 \);

![Image](image1.png)

**Fig. 3.** Kinematic parameters design window

A. Forward Kinematics

There are two options to perform forward kinematics, namely F.Kin-1 and F.Kin-2. These options of PUROLAB can be activated by clicking F.Kin-1 and F.Kin-2 buttons as illustrated in Figure 4.

![Image](image2.png)

**Fig. 4.** Application screen of F.Kin-1, F.Kin-2, Inv.Kin-1 and Inv.Kin-2

1) Forward Kinematic -1

In order to perform Forward kinematics-1, “F.Kin-1” button is selected from the application screen on Figure 4. In F.Kin-1 mode, each joint angle is activated by using sliders. The operator can perform tune or gross motion by using sliders. Tune motion can be performed by using arrow buttons on the keyboard. Gross motion is performed by using only mouse. The present position and orientation of the end-effector can be displaced by using “Current Status” button at the bottom of the slider control panel. An example of F.Kin-1 application is given on Figure 5 where \( \theta_1 = 43^\circ \), \( \theta_2 = -19^\circ \), \( \theta_3 = 4^\circ \), \( \theta_4 = -4^\circ \), \( \theta_5 = -17^\circ \) and \( \theta_6 = 0^\circ \).

![Image](image3.png)

**Fig. 5.** Forward Kinematic -1: Joint motion with sliders.

The position and orientation of end-effector is obtained by clicking the current status button as in Figure 6. Moreover, 'Reset Sliders' button on the same window brings the manipulator zero position.

![Image](image4.png)

**Fig. 6.** Current status of end-effector

2) Forward Kinematic-2

In forward kinematics-1 mode, manipulator joints are separately actuated. On the other hand in forward kinematics-2 manipulator joints are activated at the same time. User can operate the manipulator by entering the each joint value into the text boxes as illustrated in Figure 7. In this example, The joint angle values are designed as follows: \( \theta_1 = 43^\circ \), \( \theta_2 = -19^\circ \), \( \theta_3 = 4^\circ \), \( \theta_4 = -4^\circ \), \( \theta_5 = -17^\circ \) and \( \theta_6 = 0^\circ \). When the operator clicks the “move” button, the manipulator goes from the zero position to the final position and orientation as in F. Kin-1.
B. Inverse Kinematics

There are two options to perform inverse kinematics, namely I.Kin-1 and I.Kin-2. These options of PUROLAB can be activated by clicking I.Kin-1 and I.Kin-2 buttons as illustrated in Figure 4.

1) Inverse Kinematics -1

PUROLAB in inverse kinematics mode finds the joint angles according to the desired position and orientation of the end-effector in terms of the base frame. The orientation of the end-effector can be performed by using one of RPY-fixed, Euler, and RKT angle sets. Roll, pitch, yaw and Euler angle sets are commonly used in robotics. Although there are twelve roll-pitch-yaw and Euler angle sets that can be used for orientation, \( \begin{bmatrix} R_{xyz}(\alpha, \beta, \gamma) &=& R_z(\gamma)R_y(\beta)R_x(\alpha) \end{bmatrix} \) roll-pitch-yaw angles given by equation 12 and \( \begin{bmatrix} R_{xyz}(\alpha, \beta, \gamma) &== R_x(\alpha)R_y(\beta)R_z(\gamma) \end{bmatrix} \) Euler angles stated by equation 13 are used in this simulation tool.

\[
R_{xyz}(\alpha, \beta, \gamma) = R_z(\gamma)R_y(\beta)R_x(\alpha) = \begin{bmatrix}
1 & 0 & 0 \\
0 & c\beta & s\beta \\
0 & -s\alpha & c\alpha
\end{bmatrix} \begin{bmatrix}
c\gamma & -s\gamma & 0 \\
s\gamma & c\gamma & 0 \\
0 & 0 & 1
\end{bmatrix}
\]

\[
R_{xyz}(\alpha, \beta, \gamma) = R_x(\alpha)R_y(\beta)R_z(\gamma) = \begin{bmatrix}
1 & 0 & 0 \\
0 & c\beta & s\beta \\
0 & -s\alpha & c\alpha
\end{bmatrix} \begin{bmatrix}
c\gamma & -s\gamma & 0 \\
s\gamma & c\gamma & 0 \\
0 & 0 & 1
\end{bmatrix}
\]

PUROLAB allows operator to test each inverse kinematics solution of the PUMA robot manipulator. Since \( d_6 \) is accepted as zero PUMA robot manipulator has 16 inverse kinematics solutions in this application. An example of I.Kin-1 application is given on Figure 8. The position of the end-effector is accepted as \( p_x=18, p_y=4 \) and \( p_z=7 \). The orientation of the end-effector is designed by using \( R_{xyz}(90,0,0) \) Euler angle values.

2) Inverse Kinematic -2

In this mode, PUROLAB allows user to automatically generate a trajectory with several via points. When operator selects an object in the workspace, robot manipulator grips the object according to the objects position and orientation in terms

Fig. 8. Designing position and orientation of end-effector for an inverse kinematics application.

Fig. 9. An inverse kinematic application with Euler angle set.
of base frame of the robot manipulator. Operator clicks “Add Via Point” button to add a via point on the desired trajectory. Operator brings the manipulator to another via points by simply moving the object with mouse. Several via points can be selected to design a trajectory. Manipulator performs a motion passing through these via points with 7th order polynomial. An example of I.Kin-2 application is given on Figure 10 where five via points is selected for the trajectory.

Fig. 10. An example of I.Kin-2 application

CONCLUSIONS

In this paper an off-line simulation tool (PUROLAB) for PUMA robot manipulator is developed by using UNITY game engine software which provides very powerful interactive GUI facilities for operators to perform several applications. “PUROLAB” successfully performs forward kinematics, inverse kinematics and trajectory planning. PUROLAB has some important features: i) PUROLAB allows user to design kinematic parameters of her/his own robot, conveyer system and objects, ii) PUROLAB allows operator to test each inverse kinematics solution of the PUMA robot manipulator separately, iii) PUROLAB allows user to automatically generate a trajectory with several via points iv) PUROLAB has very powerful GUI and high-resolution graphics library that provides operatorsto understand fundamental of robot kinematics easily.

REFERENCES


Prototyping Multiaxis 3D Weaving: Fabrication 3D Preforms for Composites

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Abstract—Advanced preforms for textile structural composites have been made as multiaxis three-dimensional (3D) flat and circular woven preforms. Methods to weave these preforms were developed and some preform structural parameters were evaluated. Preform specifications were identified and some elastic properties of the composites were calculated. These methods and structures could be considered as feasible.

Keywords—Advanced preforms, Textile structural composites, 3D flat weaving, 3D circular weaving, carbon fiber

I. INTRODUCTION

Textile structural composites could be considered as alternative materials since they are delamination free and damage tolerant [1, 2]. The fabrication of a textile preform is made by weaving, braiding, knitting, stitching and non-woven techniques and they can generally be chosen based on end use requirements. Originally, 3D preforms were classified as yarn interlacement types. 3D preforms can be fabricated by specially designed automated looms, or existing looms that can be modified and made near-net shape to reduce scrap [3]. However, it is mentioned that they have low in-plane properties, partly due to through-the-thickness fiber reinforcement. Multiaxis 3D weaving is a relatively new concept and, additionally, bias yarn sets are introduced to the orthogonally structured preform. It is expected that multiaxis 3D preforms may enhance in-plane properties [4-7].

In this study, multiaxis 3D flat and circular woven preforms were developed to overcome the limitations of 3D preforms.

II. MATERIALS AND METHODS

A. Principles of Multiaxis 3D Flat and Circular Woven Preforms

The multiaxis 3D flat woven preform has five yarn sets as bias(+), warp (axial), filling and Z-yarns while the multiaxis 3D circular woven preform has five yarn sets as (+)-bias, axial, circumferential, and radial yarns. In Fig. 1, the schematic views of the unit-cells of multiaxis 3D flat and circular preforms are given.

In multiaxis 3D flat woven preform a new method called “tube-carrier weaving” was used. The warp yarns are arranged in a matrix of rows and columns within the required cross section. It looks to be a loose network for laying the yarns in between adjacent warp yarns. The filling yarns are laid down between each adjacent warp yarn row. They have double ends and are deposited through the preform length. The bias(+) and bias(−) yarns have two sets in which each set has the same number of warp yarn ends in each row. They are positioned in both surfaces of the preform, and are oriented toward the preform surface at an angle. Z-yarn ends are positioned between each warp column through the preform thickness. They lock all other yarn sets to provide the structural integrity of the preform.

In multiaxis 3D circular woven preform, there are two preforms developed according to “radial crossing” and “radial in-out” principles. The axial yarns are arranged in a matrix of circular rows and radial columns within the required circular cross-section. It looks like a spare network for laying the yarns in between adjacent axial yarns. Circumferential yarns are laid down between each adjacent axial yarn row. These are single-ends and deposited through the preform length. Bias yarns have two sets. They are positioned on both surfaces of the preform. First pair of bias yarns are placed on the outer surface and second pair of bias yarns are placed on the inner surface of the circular preform, but there is a circumferential yarn between bias(+) and bias(−) yarns. Bias yarns are oriented to the preform surface at an angle. Radial ends are positioned between each axial row through the preform thickness. They lock all other yarn sets to provide structural integrity of the preform where odd-numbered radial yarns are crossing the structure to the inner diameter, but even-numbered radial yarns are crossing the structure to the outer diameter. Whereas in the case of radial in-out, all radial yarns are crossing the structure to the inner diameter or the outer diameter.
B. Fiber and Matrix Specifications

Carbon fiber (PAN based Thornel™ T-300) was used to produce the multiaxis 3D flat and circular preforms. Specifications of carbon fiber and epoxy matrix (Tactix™ 123) are given in Table I.

<table>
<thead>
<tr>
<th>Specifications of Carbon Fiber and Epoxy Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon fiber</td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
</tr>
<tr>
<td>Tensile Modulus (GPa)</td>
</tr>
<tr>
<td>Modulus of rigidity (GPa)</td>
</tr>
<tr>
<td>Elongation (%)</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
</tr>
<tr>
<td>Density (g/cm³)</td>
</tr>
</tbody>
</table>

C. Carbon Preforms Produced by Multiaxis 3D Flat and Circular Weaving Methods

Fig. 2 shows the carbon preforms produced by multiaxis 3D flat and circular weaving methods. Two types of multiaxis 3D flat carbon woven preforms (Preform-1 and Preform-2) and one type of multiaxis 3D circular carbon preform (Preform-3) were produced. The preform structures are given in Table II.

In multiaxis 3D flat woven preforms, the bias(+) and bias(−) yarns are 6 K, the warp yarns are 12 K, the filling yarns are 6 K and the Z-fibers are 3 K carbon fibers used. In multiaxis 3D circular preform, the axial yarns are 12 K, the circumferential yarns are 6 K, the radial yarns are 1 K and ±bias yarns are 12 K carbon fiber used.

III. RESULTS AND DISCUSSIONS

A. Multiaxis 3D Flat Carbon Woven Preforms

In multiaxis 3D flat woven preforms, the width ratio is the main processing parameter to influence the preform fabrication during weaving. A proper tensioning system in the Z-yarn may be required in order to avoid unnecessary excessive pressure on the filling yarns, which causes local yarn distortions in the preform structure and it becomes an important processing parameter. Preform-1 and Preform-2 were the same architecture except for the bias yarn orientations. Bias yarn sets can be arranged between 15° and 75° through the in plane of both surfaces of the preform. The bias yarn orientations in Preform-1 and Preform-2 were 30° and 40°, respectively. The fractional volume results measured at preform and the calculated elastic constants are given in Fig. 3.
Results showed that the various preform structures can be crossed and radial in the preform. A new method called “tube carrier weaving” was developed. A new method called “tube carrier weaving” was used to produce multiaxial 3D flat woven preform. “Radial crossing” and “radial in-out” weaving principles were both used to produce multiaxial 3D circular woven preforms. Results showed that the various preform structures can be made thin and thick wall simple cylinders and circular complex shapes for the benefit of especially technical textile and composite industries.

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REFERENCES

An Investigation on Microstructure and Mechanical Properties of AlC Added PM Steels

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Abstract— In this work, microstructure and tensile behaviours of AlC added PM steels were investigated. The microstructure of the PM steels was characterised by optic microscope and SEM. Results indicated that 0.2 wt. % AlC added PM steel showed the highest values in yield strength (YS) and ultimate tensile strength (UTS). However, when the amount of AlC content increased from 0.2 to 0.5 wt.%, yield strength, ultimate tensile strength and elongation decreased.

Keywords— Powder metallurgy; Powder metallurgy steels; AlC; Microstructure; Mechanical properties.

I. INTRODUCTION

The production method of some parts which have been used especially in the automotive industry recently is completely based on the powder metallurgy. The production method of powder metallurgy is used as independent production choice in the manufacturing sector because its distribution of quality is homogeneous, its content is controllable and its cost per unit is low [1-2].

Microalloyed steels are described as the steels which include niobium, vanadium and titanium between % 0,05 and %0,20 percent. With the application of various hardening mechanisms and suitable thermomechanical processes, microalloyed steels are the group of materials which have superior features like high strength, high toughness, low ductile to brittle transition temperature, perfect weldability and resistance to corrosion. A great proportion of the microalloyed steels are produced as flat and tube products and in the recent years, the production of microalloyed steels for forge purposes has gained speed. Moreover, the production of microalloyed steel is carried out with the powder metallurgy method although it is not in the desired level in our day [3-4].

Certain studies are available in the literature about the relationship between the production of PM steel and microstructure mechanical properties. For instance, Erden et al. produced in their studies Ti and V microalloyed steel with the method of PM. They carried out the sintering process at 1150°C during 60 minutes and confirmed that yield strength and tensile strength increase as Ti and V ratios (% 0.1-5% 0.2) increase. They based it on the formation of precipitates like TiC(N) and VC(N) during the sintering and post-sintering cooling period [3-5].

In this study, microalloyed steel production is performed in the desired compound by adding 45% graphite powder into the Fe powder and 0.1-0.2% and 0.5% AlC as weight. Sintering process for the produced block samples was carried out at 1150°C during 1 hour at argon atmosphere. Along with the analysing of the microstructure specifications of samples like grain size, density and porosity, mechanical features were determined by implementing tensile test.

II. EXPERIMENTAL STUDY

In this experiment, steel samples were produced in the desired compound with the method of powder metallurgy. The effect of AlC ratio on the microstructure and mechanical features was examined. Microalloyed steel was produced by being mixed in the chemical compounds given in Table 1. Tensile and hardness tests, density, porosity, microstructure, ferrite-pearlite ratio and average grain size were calculated for the produced samples [6]. The results were compared to one another. Before the mixing process, powder was weighed in the ratios, the chemical composition of which is given in Table 1, on a digital precision scale which has 0.0001 precision. The weighed powders was mixed with a three axis Turbula brand mixer without marbles during one hour. Zn-stearate was used as greaser.

TABLE I CHEMICAL COMPOSITIONS OF POWDER METALLURGY STEELS

<table>
<thead>
<tr>
<th>Component</th>
<th>Graphite (wt.%)</th>
<th>AlC (wt.%)</th>
<th>Fe (wt.%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy 1</td>
<td>0.45</td>
<td>-</td>
<td>Rest</td>
</tr>
<tr>
<td>Alloy 2</td>
<td>0.45</td>
<td>0.1</td>
<td>Rest</td>
</tr>
<tr>
<td>Alloy 3</td>
<td>0.45</td>
<td>0.2</td>
<td>Rest</td>
</tr>
<tr>
<td>Alloy 4</td>
<td>0.45</td>
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<td>Rest</td>
</tr>
</tbody>
</table>

Mixed powders transformed into blocks by being pressurized unilaterally at 700 MPa pressure in a mould which is in the form of a tensile sample that is suitable to the standards of ASTM (E 8 M) powder metal material. Sintering process was carried out in argon atmosphere at 1150°C during one hour. Sintered tensile samples were tensile tested at 1 mm/min tensile speed. Stress- strain % diagrams are obtained after each experiment. The differentiation of the mechanical features is determined owing to the alteration in the AlC ratio as percentage weight in
the chemical compound by calculating the yield strength (0.2%), tensile strength and % (percentage) elongation values of the samples from these diagrams. Hardness measurement was carried out by using Vickers hardness measurement method with 0.5 kg load and hardness measurement were done from 5 different parts of the sample. Pre-tensile test images of the tensile samples are given in the Figure 1.

Microstructure examinations were carried out with Nikon Epiphot 200 brand optical microscope which has X50-X1000 zooming capacity. These images are intended to be qualified enough to represent the whole microstructure by capturing different size of images from the different parts of each sample. Etching process was carried out by sinking the samples into 2%-8% Nital solution during 4-8 seconds. After the etching process was completed, etched surfaces were cleaned with methanol and dried and then made ready for the examination under optical microscope. Density of the samples was measured with the density measurement tool according to Archimedes principle. Ferrite and pearlite ratios of the powder metal steels were determined by using the metallographic point counting method which is introduced by Gladman and Woodhead [6].

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Microstructure

Microstructure images of the samples are given in the Figure 2. As can be understood from the Figure, the structure comprises of ferrite and pearlite phases in all AlC ratios. When the microstructure images in the Figure 1 are examined, it is detected that there are partially uncovered pores on the grain borders. It is reported that tiny and round-shaped pores do not reduce the strength although it is stated in various sources that porosity affects the strength negatively [7-8].

In the Table 2, post-sintering densities and pore amounts (%) of the samples which have different ratios of A1C are given. It is observed that with an increase in the A1C ratio, post-sintering density of the samples does not change significantly and remain close to one another. The mechanical features of the components which are produced with the powder metallurgy method are related to pore ratio. Pores behave as the centres on which the tension is intensified and they contribute to crack propagation as well [6-7].

As can be seen in the Table 2, it is observed that pearlite amount is 32.25 % in the Alloy 3 while it is 21.6 % in the Alloy 1. It is an expected situation. With the A1C addition, there is a slight increase in the carbon ratio in the matrix. The A1C that is added increases the carbon ratio inside the matrix by dissolving during the sintering process. The carbon inside the matrix constitutes the cementite phase by uniting with iron and it is thought to increase the amount of the pearlite. It was also

<table>
<thead>
<tr>
<th>Component</th>
<th>Density (gr/cm³)</th>
<th>Porosity (%)</th>
<th>Volume fractions of Pearlite (%)</th>
<th>Mean linear intercept grain sizes (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy 1</td>
<td>7.21</td>
<td>8</td>
<td>21.6</td>
<td>29.7</td>
</tr>
<tr>
<td>Alloy 2</td>
<td>7.02</td>
<td>10.34</td>
<td>31.25</td>
<td>24.5</td>
</tr>
<tr>
<td>Alloy 3</td>
<td>7.25</td>
<td>8.02</td>
<td>32.25</td>
<td>22.3</td>
</tr>
<tr>
<td>Alloy 4</td>
<td>6.91</td>
<td>11.48</td>
<td>32.75</td>
<td>26.9</td>
</tr>
</tbody>
</table>
observed that the average grain size decreased to 18.6 µm in the Alloy 3 while it is 29.7 µm in the Alloy 1. A1N precipitate is thought to arise during the sintering and post-sintering cooling processes and thereby preventing the grain growth. With an increase in the carbon ratio, pearlite amount is observed to increase and average grain size is observed to decrease. It is an expected situation. The studies supporting this result are available in the literature [8-9]. It is observed that average grain size increases a little with an increase in the A1C ratio as weight from 0.2% to 2%. This can be thought to result from the formation of big A1C precipitates on the borders of the grains [9-10]. The fact that precipitates pile up on the borders of the grains leads to an increase in the amount of the pores. Therefore, the big precipitates which arise lead to the growth of the average size of the grain because they can’t prevent the grain growth adequately.

B. Mechanical Properties

Table 3 demonstrates the yield strength, tensile strength, percentage elongation and hardness values while Figure 2 demonstrates the tensile-elongation diagrams of the sintered samples. As can be seen in Table 3 and Figure 2, when A1C ratio increases to 0.2% as weight, there is an increase in the yield and tensile strength and there is not a change in the percentage elongation values generally. Carbide, nitride and carbonitride precipitates which are formed by A1 element enable material to be small grained by preventing the austenite grain size and recrystallization of the austenite. The strength increases with more grain boundary on the small grained structure and the prevention of the dislocation movement by this grain boundary. Reduction in the grain size contributes to percentage elongation of the material. Along with these, the precipitates that are formed up contribute to the increase of the yield and tensile strength with various strength increasing mechanisms like precipitation hardening, dispersion hardening and clustering hardening [11-13].

Table 3

<table>
<thead>
<tr>
<th>Component</th>
<th>Yield Strength (MPa)</th>
<th>Tensile Strength (MPa)</th>
<th>Elongation (%)</th>
<th>Hardness (0.5HV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy 1</td>
<td>144</td>
<td>252</td>
<td>13</td>
<td>68</td>
</tr>
<tr>
<td>Alloy 2</td>
<td>171</td>
<td>316</td>
<td>17</td>
<td>127</td>
</tr>
<tr>
<td>Alloy 3</td>
<td>189</td>
<td>355</td>
<td>15</td>
<td>153</td>
</tr>
<tr>
<td>Alloy 4</td>
<td>109</td>
<td>284</td>
<td>13</td>
<td>91</td>
</tr>
</tbody>
</table>

However; there is a decrease in the yield strength, tensile strength, hardness and percentage elongation values when the amount of the A1C which is added to PM steels increased from 0.2 % to 0.5 % as weight. This situation can be attributed to the decrease in the density in the 0.5 % A1C alloy ratio. Such features as strength, ductility and conductivity are dependent on the density; in other words, porosity and pore pattern [8]. Besides, high proportion of A1C inside the steel leads to the brittle of the material and reduces the strength by leading to over-precipitation hardening [10].

IV. GENERAL CONCLUSIONS

Holding three different compound ratios (%0.1 – 0.2 and 0.5), A1C alloyed PM steel is produced by implementing cold pressurizing and sintering at argon atmosphere and the following results below are obtained from this experiment.

Alloyed steel which is added A1C is able to be produced with powder metallurgy method. Solid solution hardening and precipitation hardening which arises during the sintering process or post-sintering cooling process increase the strength of the steel. 0.2 % A1C added PM steel is observed to have the highest yield strength and tensile strength.

0.1% and 0.2% A1C added alloyed steel samples exhibit smaller grain size compared to nonalloyed steels. This situation results from prevention of the grain growth by carbide and nitride particles formed up. Moreover, in the steel sample which is added 0.5% A1C as weight, increase in the grain size is observed. The reason for this can be thought as the formation of A1C and A1C(N) precipitates at bigger sizes on the borders of the grains. Yield strength and tensile strength decreased with an increase in the amount of the A1C from 0.2 to 0.5 as weight.

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PROPERTIES OF EPOXY COMPOSITES INCLUDING VOLCANIC TUFF

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Abstract – In this study, epoxy composites were synthesized using tuff as filler and three types of plasticizers. Physico-mechanical and thermal properties of the epoxy composites were investigated with different analyses and tests. Well-dispersed epoxy composites were obtained according to XRD and SEM results. The epoxy composite including 3 wt% tuff had maximum tensile strength and elongation at break values as 244.7 MPa and 2.947%, respectively. Incorporation of plasticizers especially PEG decreased brittleness of the composites. Adhesion percent of neat ER slightly decreased with the addition of tuff and plasticizers. It was determined that corrosion resistance of the composites was not affected negatively in different corrosive solutions. The water sorption of the composites decreased with tuff; however plasticizers especially PEG caused to increase water sorption. The decomposition temperature of the composites were improved with tuff addition in spite of a slight reduction in initial decomposition temperatures with plasticizers.

Keywords - Composite, epoxy resin, volcanic tuff, physico-mechanical and thermal properties

I. INTRODUCTION

Polymer composites are well-known as one of the most promising advanced materials in many engineering applications [1]. Epoxy based polymer composites have attracted interest due to many advantages of epoxy such as high strength, low shrinkage, great chemical resistance, and heat stability [2]. Epoxy resins are widely used in the fields of electronics, adhesives, coatings, and composites [3]. Flammability and brittleness are unfortunately among drawbacks of epoxy resins which restrict usage capacity of them [4-5]. So, flexible polymers, inorganic solid particles, elastomers, and natural particles are utilized to decrease brittleness in addition to flammability degree [6-7]. While soft materials have plasticizing properties to reduce hardness, rigid solid particles generally improve thermal resistance for epoxy resins [8].

Volcanic tuffs which consist of siliceous and aluminous components are cheap and abundant inorganic materials in Turkey. The tuffs have been effectively evaluated as admixture in pozzolanic cements and surrounding material for modelling the ground heat exchange in air conditioning process etc. recently [9-10].

In this study, epoxy composite materials including tuff were synthesized. Physico-mechanical and thermal properties of the materials were examined with different analyses and tests. And also, the effects of three types of plasticizers on the properties of these epoxy composites were investigated.

II. MATERIALS AND METHOD

A. Materials

NPEF 170 based on bisphenol F epoxy resin and the tuff were used as matrix system and filler, respectively. The chemical composition of tuff was Na$_2$O 4.8%, MgO 0.3%, Al$_2$O$_3$ 14.0%, SiO$_2$ 71.5%, P$_2$O$_5$ 0.1%, K$_2$O 4.1%, CaO 1.0%, TiO$_2$ 0.4%, MnO 0.1%, Fe$_2$O$_3$ 2.8%. The hardener commercially known as Epamine PC17 had aliphatic amine structure. 2,4,6-tris(dimethylaminomethyl)phenol was used as an accelerator. Three types of plasticizers were polyethylene glycol (PEG-400), diethylene glycol (DEG) and monoethylene glycol (MEG).

B. Preparation of Epoxy Composite Materials

The tuff by the weight of 0, 3, 5, 10, and 15 and epoxy resin (ER) were mixed mechanically to provide well-dispersed blends. After the sonication was applied to blends for chain mobility of ER, the hardener by 25 wt% was added to blends. In the following step, the accelerator was dropped to blends and they were poured into the mould. The curing and post-curing conditions were adjusted as 40 °C for 4 h and 80 °C for 4 h, respectively. In the second part of the experiment, another epoxy composites were prepared with the addition of fixed 5 wt% tuff and plasticizers at 5 wt% under same experimental method.

C. Characterization of Epoxy Composite Materials

X-ray diffraction (XRD) measurements were performed at a scan rate of 2 min$^{-1}$ in the range of 10 - 80$^\circ$ using Bruker D8 Advance X-ray diffractometer. Surface morphology of epoxy composites were investigated at an accelerating voltage of 20 kV using SM Zeiss LS-10 scanning electron microscope (SEM) after gold-coating of epoxy composites to prevent charging. Tensile properties were examined using Stretch and Pressing Equipment TST-Mares/TS-mxe at constant rate of 5 mm/min until fracture. Hardness of the epoxy composites were determined using Shore Durometer TH 210 tester with calculating arithmetic mean of data taken from front and back surfaces of epoxy composites. Adhesion ability of epoxy
composites was evaluated as per Lattice notch method [11] and adhesion percent was calculated using the following equation:

$$\text{Adhesion, } \% = \left( \frac{a - b}{a} \right) \times 100$$  \hspace{1cm} (1)

where $a$ is the total number of the squares on the steel surface and $b$ is the number of squares separated from steel surface. The corrosion resistance of the epoxy composites was examined with observing them in 3\% NaCl, 10\% H$_2$SO$_4$, 10\% NaOH solutions for two weeks at room temperature [12]. Water sorption test was carried out as per ASTM D 570 Standard for two weeks at room temperature. Water sorption percentage was calculated using the following equation:

$$\text{Water sorption, } \% = \left( \frac{m_1 - m_2}{m_2} \right) \times 100$$  \hspace{1cm} (2)

where $m_1$ is the mass of sample at any time and $m_2$ is the initial mass of sample. Thermogravimetric analyses (TGA) were carried out using Lab. METTLER STAR SW thermal analyzer under the N$_2$ atmosphere with heating rate of 10 °C/min.

III. RESULTS

XRD patterns of neat ER, tuff, and epoxy composites including 5 wt\% tuff and plasticizers are shown in Fig. 1. The tuff intensively exhibited characteristic peaks between 20 and 40°, while neat ER had only broad peak at about 20°. The peaks belonged to tuff were almost disappeared when the 5 wt\% tuff was added to neat ER. And also, no sharp peak was observed with the addition of 5 MEG, DEG, and PEG to the epoxy composite including 5 wt\% tuff, respectively. It can be deduced from the XRD results that uniform dispersion of tuff and plasticizers was most likely obtained in the neat ER. SEM images of neat ER and epoxy composites including 5 wt\% tuff and plasticizers are shown in Fig. 2. Typical smooth morphology of neat ER that is generally evidence of brittle structure was shown in Fig. 2a. It was clearly seen homogeneous dispersion of 5 wt\% tuff in the neat ER in Fig. 2b. Although a small agglomeration was observed for epoxy composite including 5 wt\% MEG in Fig. 2c, well-dispersed structure was obtained for epoxy composites including 5 wt\% DEG and PEG in Fig. 2d and Fig. 2e, respectively.
Tensile strength ($\sigma$), elongation at break ($\varepsilon$), and hardness values of neat ER and epoxy composites are shown in Table 1. The maximum $\sigma$ and $\varepsilon$ was observed for epoxy composite including 3 wt% tuff; however more than 3 wt% tuff addition decreased $\sigma$ and $\varepsilon$ values. Due to rigid structure of tuff, an increase in hardness of the epoxy composites was determined. When the effect of plasticizers on the tensile properties of epoxy composites was investigated, epoxy composite including MEG had the lowest $\sigma$ and $\varepsilon$ values. These plasticizers especially PEG decreased brittleness of the epoxy composites owing to its flexible structure.

Table I Tensile Properties of Neat ER and Epoxy Composites

<table>
<thead>
<tr>
<th>Sample</th>
<th>$\sigma$ (MPa)</th>
<th>$\varepsilon$ (%)</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>neat ER</td>
<td>146.9</td>
<td>1.694</td>
<td>79</td>
</tr>
<tr>
<td>ER / 3 wt% tuff</td>
<td>244.7</td>
<td>2.947</td>
<td>80</td>
</tr>
<tr>
<td>ER / 5 wt% tuff</td>
<td>235.1</td>
<td>2.573</td>
<td>82</td>
</tr>
<tr>
<td>ER / 10 wt% tuff</td>
<td>185.6</td>
<td>2.000</td>
<td>85</td>
</tr>
<tr>
<td>ER / 15 wt% tuff</td>
<td>138.1</td>
<td>1.333</td>
<td>87</td>
</tr>
<tr>
<td>ER / 5 wt% tuff / 5 wt% MEG</td>
<td>120.3</td>
<td>1.000</td>
<td>79</td>
</tr>
<tr>
<td>ER / 5 wt% tuff / 5 wt% DEG</td>
<td>130.4</td>
<td>1.058</td>
<td>78</td>
</tr>
<tr>
<td>ER / 5 wt% tuff / 5 wt% PEG</td>
<td>135.0</td>
<td>1.173</td>
<td>75</td>
</tr>
</tbody>
</table>

The adhesion percent of neat ER, 96%, negligibly decreased until 90% with increasing amount of tuff. It can be explained that incorporation of tuff to the neat ER may slightly decrease cross-linking density of ER chains. The adhesion percent of epoxy composite including 5 wt% tuff decreased from 94% to 90 and 88% with the addition of DEG and PEG, respectively. However, any change in the adhesion percent was not identified for epoxy composite including MEG.

At the end of the observations for corrosion resistance of epoxy composites to different environmental conditions, there was no difference in the appearance of the epoxy composites and corrosive solutions. In other words, any crack, swelling, fracture was not determined for epoxy composites. And also, any color change was not observed in the epoxy composites and the corrosive solutions.

Water sorption of neat ER and epoxy composites as a function of immersing time in water is shown in Fig. 3. It was clearly seen that water sorption of neat ER, 0.88%, efficiently decreased with increasing amount of tuff. It can be expressed with the barrier effect of tuff which limits water penetration to the epoxy composite. The effect of plasticizers on the water sorption capacity of epoxy composite including 5 wt% tuff is shown in Fig. 4. The water sorption of epoxy composites increased with the incorporation of plasticizers especially PEG. A remarkable increase was identified with PEG addition.
due to more hydroxyl groups in its structure that tend to combine with hydrogen in water molecules.

The effect of plasticizers on the water sorption of epoxy composites including 5 wt% tuff is shown in Fig. 6. The plasticizers slightly decreased initial decomposition temperature of epoxy composite including 5 wt% tuff; however the residue values of epoxy composites including plasticizers were quite close to epoxy composite including 5 wt% tuff.

TGA curves of neat ER and epoxy composites including tuff are shown in Fig. 5. It was obviously seen that decomposition temperatures of neat ER was enhanced with the addition of tuff. The residue which limits to release combustible gases at 700 °C for neat ER was increased from 20.50% to 29.20% with adding 10 wt% tuff. Thermal resistance of tuff was higher than neat ER, so thermal stability of the epoxy composites was improved. The effect of the plasticizers on the thermal properties of the epoxy composite including 5 wt% tuff is shown in Fig. 6. The plasticizers slightly decreased initial decomposition temperature of epoxy composite including 5 wt% tuff; however the residue values of epoxy composites including plasticizers were quite close to epoxy composite including 5 wt% tuff.

IV. CONCLUSION

Epoxy composites including tuff at different weight ratios were easily prepared. In addition to this experiment, the effect of plasticizers on the physico-mechanical and thermal
properties was investigated. XRD and SEM results showed that good interaction between neat ER and tuff and/or plasticizers was achieved in spite of a small agglomeration in the epoxy composite including MEG. The epoxy composite including 3 wt% tuff had the highest σ and ε value among the others. While the hardness of epoxy composites was increasing with the tuff addition, plasticizers decreased brittleness of the epoxy composites. The epoxy composites including PEG were less brittle than the other composites. The adhesion capacity of neat ER did not deteriorate with the incorporation of tuff and plasticizers. The corrosion resistance of the neat ER was preserved under the influence of tuff and plasticizers addition. An increase in the amount of tuff decreased water sorption of the epoxy composites; however plasticizers especially PEG led to increase water sorption of the composites. Thermal stability of the epoxy composites was enhanced with the tuff addition. Although initial decomposition temperatures of the composites slightly decreased with plasticizers, decomposition temperatures in high temperatures were quite close each other in all composites.

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Low Velocity Impact Response of Nano-CaCO$_3$ Modified Epoxy/Carbon Fiber Laminated Nanocomposites

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*Department of Mechanical Engineering, Selçuk University, Turkey

Abstract—Nano calcium carbonate (CaCO$_3$) is used to enhance mechanical performance of fiber reinforced polymer composites (FRPs). In the present study, the influence of nano CaCO$_3$ particles have been examined by using the low-velocity impact tests on carbon fiber reinforced laminated epoxy nanocomposite to determine its impact response. At the beginning, several rates of nano CaCO$_3$ particles which are quoted epoxy (1 to 3 wt %) were dispersed into acetone, than this solution was added into epoxy resin. After acetone was removed via vacuum oven, nanocomposites were manufactured by low cost Vacuum Assisted Resin Infusion Method (VARIM). The test performed according to ASTM-D-7136 standard with 2, 2.5 and 3 m/s impact velocities on 100 x 150 mm tests specimens. Considering to impact force and displacement versus interaction time entail results, nano CaCO$_3$ particles provided significant improvement on impact damage resistance. The highest damage resistance and more efficient energy absorption observed addition of 2 wt % nano CaCO$_3$ particles as an optimal ratio.

Keywords—Epoxy modification, nano calcium carbonate, impact behaviour, vacuum resin infusion method (varim)

I. INTRODUCTION

The mechanical property of neat epoxy matrices can be enhanced by modifying to provide high stiffness and strength [1]. In this regard, nanoscale reinforcements have attracted considerable attention to modifying epoxy in the field of conducting polymer nanocomposites to ensure good mechanical properties, excellent electrical and thermal conductivities for many applications [2-4]. There is a relationship between low-velocity impacts and a series of micro-cracking generated in the matrix during the impact event [6]. These sub-critical cracks may not produce to damage, but cause local stress redistribution and energy concentration. Nanocomposites provide opportunities causing new fracture behaviour beyond those found in conventional materials [7].

The nanocomposites containing different nanoparticles have been further employed as the matrix material to produce nanoparticle modified fiber reinforced polymer composites (FRPs) that possess improve the mechanical and fracture properties [7-9]. However, so far few studies have been reported on CaCO$_3$ nanoparticles modified carbon fiber reinforced polymer composites (CFRPs) [10]. The aim of this paper is to investigate the low-velocity impact response of CaCO$_3$ nanoparticles modified carbon fiber reinforced laminated polymer composites.

II. MATERIALS AND PROCEDURE

A. Nanocomposite Manufacture

The epoxy resin as the commercially available diglycidylether of bisphenol-A (DGEBA) supplied by Momentive Hexion Inc. Nano-CaCO$_3$ was purchased from Shandong Dazhan Nano Materials Co. Carbon fiber fabric and the all other vacuum infusion equipments were provided by Dost Kimya Inc., Turkey. The area density of carbon fiber was 300 g/m$^2$ and each bundle consisted of 12000 filament.

Due to the importance of the dispersion of nanoparticles within epoxy resin, initially the nano-CaCO$_3$ which are quoted epoxy (1 to 3 wt %) were dispersed into acetone, than this solution was added into epoxy resin. The mixtures were stirred for 30 min with an ultra sonicator. The mixture was heated up to 70 °C for 24 h in a vacuum oven to remove the acetone from epoxy mixture. After acetone was removed via vacuum oven, curing agent was added in to the epoxy mixtures appropriate with supplier instructions and the mixture was mixed manually for 5 min. Neat epoxy suspension was also prepared same conditions for control.

Carbon fiber reinforced epoxy matrix laminated nanocomposites were prepared by means of VARTM. Six layers of woven carbon fabrics (350 mm×500 mm) were cut and the fiber preform was stacked on VARTM loom. In contrast to the standard VARTM methods, firstly hand lay-up method applied on each woven carbon fabric layers, and the resin impregnated woven fiber were put into a vacuum bag. In this way, filtering of nanoparticles by fiber was also prevented. After degassing, the temperature was increased to 80 °C for 1 h, at 120 °C for 2 h. After curing process, the system was cooled gradually down to the room temperature, so as to avoid the unwanted shrinkage in the laminates.

Finally, the cured panel was taken out and specimens were cut according to ASTM-D-7136 standard.
B. Experimental Techniques

The produced composite laminates have been subjected to low-velocity impact tests in accordance with ASTM-D-7136 standard. Impact tests were performed with a drop tower by adjustable the height of impactor. The impactor has a hemispherical shape with a spherical hardened steelhead of 12 mm diameter and 6.35 kg mass.

The force variations were measured by a sensor in millivolts scale. The interaction force variations between the impactor and the sample were recorded using NI Signal Express software. The sampling rate of data acquisition system is 10 kHz. As described in the regarding standard, the Newton’s second law was used to express the velocity and displacement of impactor versus time [11]. The tests were repeated three times at 2, 2.5 and 3 m/s impact velocity levels.

To prevent the repetitive impacts on the composite specimens, system has an anti-rebounding mechanism which catches immediately the impactor after completed the initial impact.

Data received from the force sensor during impact were processed by using Newton’s second law. It is known that first integration of acceleration as a function of time gives the velocity and second integration gives displacement.

III. RESULTS AND DISCUSSIONS

The low velocity impact performance of the neat and nanoparticle modified composite materials were evaluated using different parameters that have been performed in literatures which include the force-time, the absorbed energy-time and force-displacement interactions [12–14].

A. Force-time curves

Fig. 1 shows the force responses for the four different CFRP laminate specimens which include different nano-CaCO₃ particles range from 0 wt% to 3 wt% depend on 5, 10, 15 Joules impact energy levels. It is seen that the general behavior of the specimens show differences in terms of peak load and beginning slope which is parameters of materials rigidity. Also Fig. 1 demonstrates that the maximum peak load value and slope are achieved in case of 2 wt% CaCO₃ nanoparticles loading.

On the other hand, 3 wt% CaCO₃ nanoparticles loading causes decline both achieved maximum force and slope. It is believed that this deterioration of performance is caused by locally nanoparticle agglomeration.

When the figures (Fig. 1.a, Fig. 1.b and Fig. 1.c) are compared, it is clearly seen that as the impact energy increases, the peak force on the specimens are increase.

Another noticeable issue is evolution of interaction time. Fig. 1 demonstrates that 2 wt% CaCO₃-Epoxy/CF is relatively exhibited shortest interaction time. By the reason of the enhanced rigidity of modified composite laminates, bending capability is reduced and therefore interaction duration is decreased the moment of impact.

Fig. 1. Force and time curves at different impact velocity level for neat and modified specimens (a) 2 m/s, (b) 2.5 m/s, (c) 3 m/s.

B. Force-displacement curves

Fig. 2 shows the relation between impact force and displacement for composite laminates at different impact energy levels. It is observed that curves exhibit nearly linear behavior at the beginning of the curves. After reaching peak force value, the force decreases non-linearly.
The slope of force-displacement curves is criteria of bending stiffness under impact loading [11]. Inter-layer and intra-laminar interaction play important role in this region. Increasement of slope indicates that the better interfacial interaction than neat epoxy specimens. 2 wt% CaCO\(_3\) nanoparticles loading indicates well matrix-fiber interactions.

Fig. 2 clearly illustrates that as the impact energy increases, the contact force and the displacement also increase which is associated with damage amount in laminates.

C. Energy-time curves

Energy-time curves of laminates are seen in Fig.3. Rebound energy and absorbed energy relation are shown as representatively for one specimen in Fig. 3.a. It is clearly seen that in case of 3 wt% CaCO\(_3\) nanoparticle loading, laminates absorbed more energy. This situation also means that material is more destroyed. Because the absorbed energy increases, this energy will be exert to damage formation in laminates. In addition, the minimum energy absorption occurs in 2 wt% CaCO\(_3\) nanoparticles loading.

Fig. 2. Force and displacement curves at different impact velocity level for neat and modified specimens (a) 2 m/s, (b) 2.5 m/s, (c) 3 m/s.

Fig. 3. Energy and time curves at different impact velocity levels for neat and modified specimens (a) 2 m/s, (b) 2.5 m/s, (c) 3 m/s.
IV. CONCLUSIONS

The experimental results for the low velocity impact response (impact velocity at 2, 2.5 and 3 m/s) of nanocomposites have been presented in this paper. Three types of nanocomposite specimens prepared from modified epoxy resin. Neat epoxy samples prepared for control. After modifying with nanoparticles, the impact peak forces and slope of force-time curves increase, which means that the nanoparticles enhance the rigidity of carbon fiber reinforced epoxy composites.

The impact properties of the 1 wt% and 2 wt%-Epoxy/CF nanocomposites are higher than 0 wt% and 3 wt%-Epoxy/CF specimens owing to better adhesion at the fiber-matrix and laminate interface.

Impact behavior gradually reduce in condition of increased nanoparticle content because that the nanoparticle agglomerates produce the inhomogeneous particle shape and increase the composite brittleness.

REFERENCES


Studies on the Preparation and Mechanical Performance of the Nanoclay/Multiwall Carbon Nanotube Hybrid Epoxy Nanocomposites

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Abstract — There are many studies have been carried out about nanomaterials in the last decade. Under the guidance of these studies, the mechanical properties of composite materials can be changed by adding nanoparticles. Multi-wall carbon nanotubes (MWCNT) and nanoclays (NC) have been well known nanoparticles, which can be used to develop mechanical properties of diglycidyl ether of bisphenol A (DGEBA) epoxy composite materials due to their superior properties. In this paper, effects of hybridization with NC and MWCNT were investigated for epoxy modification. At the beginning, nanoclay epoxy nanocomposites were prepared by conventional casting in stainless steel mold to detect optimum ratio of nanoclay range from 1 to 5 wt %. According to the result of mechanical test, optimum ratio of nanoclay particles was found at 2 wt %. Then, 0.1, 0.3, 0.5, and 0.7 wt % MWCNT added into epoxy resin which includes 2 wt % nanoclay to find out the contribution of MWCNT on mechanical properties, respectively. Scanning Electron Microscopy (SEM) and optical microscopy analysis techniques were used to understand the toughening mechanisms of the nanocomposites.

Keywords— hybrid epoxy, mechanical performance, multiwall carbon nanotube, nanoclay, nanocomposites

I. INTRODUCTION

Polymers materials especially thermosets have been commonly used for adhesives, various engineering parts and matrix for composite materials due to their superior mechanical properties compared to thermoplastic polymers. However, they have usually weak fracture properties such as toughness, brittle and vulnerable crack. The addition of nanoparticles to polymers increases its strength and sometimes decreases the toughness due to particles agglomerate, inappropriate concentration. Nanoparticles have been widely studied by researchers for enhancement of mechanical properties of polymer composite materials. Carbon nanotubes (CNT) have demonstrated high properties to improve the mechanical properties of polymers and electrical properties [1-2]. Florian et al. studied the effect of different CNT on tensile test and fracture toughness [3]. Schadler et al. studied MWCNT/epoxy composites under tensile and compressive loading and found compressive modulus of the composite to be higher in MWCNT/epoxy composite compared to the neat composites [4].

However, CNTs are both expensive and unhealthy [5]. Cheap organic materials like nanoclays are also popular for composites. Nanoclays, which are layered structures, can be reinforced the matrix to improve mechanical properties. Also, they use for thermal and moisture barrier inside of matrix due to their thermal stability and environmental degradation resistance properties [6]. Chowdhury et al. [7] studied thermal and mechanical behaviour of nanoclay-epoxy composites. They obtained best mechanical strength for 2 wt. % of nanoclay. Bagherzahed et al. studied increasing barrier and anticorrosive properties with increasing nanoclay content [8]. Kim et al. studied fracture toughness of epoxy adhesive with nanoparticle additives such as mixed carbon black and nanoclay in epoxy [9]. Islam et al. studied that modified fiber epoxy composite with 2 wt. % NC and 0.3 wt. % MWCNT on 3 point bending test, dynamic mechanical analysis and low impact test [10].

In this study, NC/Epoxy nanocomposites were produced from 1 to 5 wt %. According to the result of mechanical test of NC/Epoxy nanocomposites, optimum ratio of nanoclay was found at 2 wt %. 2 wt % nanoclay and 0.3, 0.5, 0.7, and 1 wt % MWCNTs have been added epoxy matrix. Tensile test and Flexural test have been conducted to characterize the modified epoxy and then compared to neat epoxy composites.

II. MATERIALS AND PROCEDURE

The epoxy resin and MWCNT were supplied by Momentive Hexion Inc. Nanoclay was purchased from Esan Chemical Industry.

The NC 2 wt% and MWCNT weight content was varied 0.3, 0.5, 0.7 and 1 wt%. The acetone and powder NC/MWCNT were stirred for 30 min with an ultra sonicator. Epoxy was added after dispersing process in NC/MWCNT/Acetone and evaporated acetone at 70 °C for 24 hours. Then, curing agent was mixed NC/MWCNT/Epoxy. The mixture was ultrasonicated for 30 min and degassed at 25°C/0.6 bar for 30 min. The steel mold (Fig. 1 (a)) covered with release agent and mixture was poured into preheated mold Fig.1 (b)-(c). Curing was performed at 80 °C for 1 h, at 120 °C for 2 h and then it was slowly cooled to room temperature in the oven. Then, specimens were unmold from steel mold, which made according ASTM D7264/ D7264M-07 standards for flexural test and ASTM D4762 - 11a for tensile test. All samples were removed from mold and conventionally polished with SiC.
sandpapers with grit numbers of 800 to minimize effect stress concentration caused by sharp edges. Also, flexural specimens have been cut in accordance with test standards.

III. RESULT AND DISCUSSION

A. Flexural Test Results

At the beginning, three point bending tests were conducted to understand the effect of nanoclay matrix modification on flexural behaviour. Flexural load-deflection curves of modified NC/Epoxy with as a function of different weight percentages of nanoclay in the epoxy resin showed in Fig. 2. It is clear from this figure that flexural load and deflection values of the modified epoxy loaded with 1 and 2 wt% nanoparticles are much greater than neat epoxy sample. However, the flexural loads were decreased in case of the epoxy containing 3, 4 and 5 wt% nanoparticles. This reduction in the load was related to the nanoparticle agglomerations.

Then, according to result of flexural test of NC/Epoxy nanocomposites, 2 wt% NC ratio was used for NC/MWCNT/Epoxy nanocomposites’ flexural test. The curves of NC/MWCNT/Epoxy nanocomposite with 2 wt% NC and 0.1, 0.3, 0.5 and 0.7 wt % MWCNT in the epoxy matrix shown in Fig. 3. Although, loaded with 2 wt% NC and 0.1% MWCNT nanoparticles did not change significantly, it can be seen that the curves values of NC/MWCNT/Epoxy nanocomposite loaded with 2 wt% NC and 0.3 wt% MWCNT nanoparticles are greater than neat one in Fig. 3. Loaded with 0.5 and 0.7 wt% MWCNT nanoparticles did not show good mechanical properties.

Table 1 summarizes the loads and deflections at the peak loads both NC/Epoxy and NC/MWCNT/Epoxy nanocomposites. The flexural test result of NC/Epoxy nanocomposites with 2 wt% have increase of 40.1 %. On the other hand, 2wt% NC – 0.3 wt% MWCNT/Epoxy nanocomposite have increase of 19.2 % compared to 2 wt% NC/Epoxy and increase of 67.1 % compared to neat epoxy composites.

<table>
<thead>
<tr>
<th>Material</th>
<th>Load (N)</th>
<th>Displacement (mm)</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 wt% NC/Epoxy</td>
<td>209.1</td>
<td>4.35</td>
<td>-</td>
</tr>
<tr>
<td>2 wt% NC/Epoxy</td>
<td>293.1</td>
<td>5.36</td>
<td>40.1 %</td>
</tr>
<tr>
<td>2 wt% NC-0.3 wt% MWCNT/Epoxy</td>
<td>349.4</td>
<td>5.75</td>
<td>19.2 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>67.1 %</td>
</tr>
</tbody>
</table>

B. Tensile Test Results

Stress-strain curves of different weight percentages of NC/Epoxy are shown in Fig.4. It can be seen highest increase of the tensile strength and strain is achieved with the 2 wt% nanoclay loading. Also this figure show, tensile properties are deteriorate in case of over the 2 wt% nanoclay loading. It is believe that this event occur due to the agglomerations of nanoclay.
The optic micrograph of the neat epoxy sample displayed smooth fracture surface after the flexural test, due to their innate the poor toughness as shown in Fig.6 (a). The optic micrograph of 2 wt% NC/Epoxy indicated more ductile and plastic deformation region in Fig. 6 (b) compared to neat epoxy sample. The optic micrograph of 2 wt% NC – 0.3 wt% MWCNT modified nanocomposites showed a rough fracture surface with evidence of relatively plastic deformation, indicating a relatively ductile fracture surface compared to 2 wt% NC/Epoxy samples (Fig. 6 (c)). These differences clearly show the higher fracture toughness of NC and MWCNT modified epoxy resin compared to that of the neat epoxy and NC modified epoxy resin. The evidences of 2 wt% NC – 0.3 wt% MWCNT/Epoxy like rough surface, plastic deformation were more than others.

C. Analysis of Fracture Surface

To better understand the toughening effect of NC and MWCNT on the nanocomposites, flexural and tensile fracture surfaces of the NC/Epoxy and NC/MWCNT/Epoxy nanocomposites were observed using SEM and optical microscope.

Table II summarizes the stress and strain curves at the peak loads both NC/Epoxy and NC/MWCNT/Epoxy nanocomposites. The tensile test result of NC/Epoxy nanocomposites with 2 wt% have increasement of 37.03 %. On the other hand, 2 wt% NC – 0.3 wt% MWCNT/Epoxy nanocomposite have increasement of 34.37 % compared to 2 wt% NC/Epoxy and increasement of 84.12 % compared to neat epoxy composites.

**TABLE II. THE STRESS AND STRAIN VALUES AT THE PEAK LOADS OF NC/EPOXY AND NC/MWCNT/EPOXY**

<table>
<thead>
<tr>
<th>Material</th>
<th>Stress (MPa)</th>
<th>Strain</th>
<th>Increase (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 wt% NC/Epoxy</td>
<td>45.1</td>
<td>0.026</td>
<td>-</td>
</tr>
<tr>
<td>2 wt% NC/Epoxy</td>
<td>61.8</td>
<td>0.03</td>
<td>37.03 %</td>
</tr>
<tr>
<td>2 wt% NC–0.3 wt% MWCNT/Epoxy</td>
<td>83.04</td>
<td>0.035</td>
<td>34.37 %</td>
</tr>
<tr>
<td>2 wt% NC–0.7 wt% MWCNT/Epoxy</td>
<td>83.12</td>
<td>0.035</td>
<td>84.12 %</td>
</tr>
</tbody>
</table>

Fig. 5 Tensile curves of NC/MWCNT/Epoxy nanocomposite

Fig. 4 Tensile curves of NC/Epoxy nanocomposite

Fig. 6 Fracture Surface after flexural test

After the tensile test, fracture surface images can be seen in Fig. 7. Congruently, Fig. 7 (a) shown that neat epoxy sample displayed smooth fracture surface and it has a poor toughness. Besides, the optic micrograph of 2 wt% NC/Epoxy shown rough and plastic deformation area in fracture surface compared to neat epoxy composite sample in Fig. 7 (b). In the surface image of 2 wt% NC – 0.3 wt% MWCNT, it can be seen sharp plastic deformation and rough yielding area (Fig. 7 (c)). Consequently, these evidences of NC/MWCNT/Epoxy nanocomposite were more than other fracture surfaces.

Fig. 7 Fracture Surface after tensile test

In order to understand the improvement of toughness mechanism in 2 wt% NC – 0.3 wt% MWCNT/Epoxy nanocomposite, SEM images of fracture surfaces are shown in Fig. 8. The SEM micrographs of 2 wt% NC in the epoxy matrix are shown in Fig.8 (a). The fracture morphology of the 2 wt% NV/Epoxy specimen shows very homogenous nanoparticle dispersion in Fig.8 (a). There are a number of toughening mechanisms in literature which can be associated to the amount of energy absorbed and fracture toughness increases as the
main toughening mechanisms are crack pinning and crack bridging [11-12]. Nanoparticle bridging mechanism is clearly seen in 2 wt% NC/Epoxy nanocomposite (Fig. 8 (b)). Also, both crack pinning and bridging mechanisms can be seen in 2 wt% NC – 0.3 wt% MWCNT/Epoxy specimens (Fig. 8 (c)).

toughness mechanisms such as crack pinning, nanoparticle bridging were apparent in the SEM micrographs and these mechanisms related to amount of energy absorbed. Fracture toughness increase with these mechanisms.

IV. CONCLUSIONS

Experimental results show that the 2 wt% NC and 2 wt% NC – 0.3 MWCNT modification significantly improved flexural strength of epoxy nanocomposite compared to neat epoxy by 40% and 67%, respectively. This tendency for tensile strength has maintained to be 37% and 84%, respectively. The results of the conducted experiments show that the NC and MWCNT modification in epoxy resin enhance flexural and tensile properties of nanocomposites. Fracture surface analysis such as optic and scanning electron microscopy supported this conclusion. Plastic deformation, ductile and yielding area can be seen in optical images for nanocomposite materials. Besides, toughness mechanisms such as crack pinning, nanoparticle bridging were apparent in the SEM micrographs and these mechanisms related to amount of energy absorbed. Fracture toughness increase with these mechanisms.

REFERENCES


Fig. 8 SEM micrographs of fracture surface
Wear and Exfoliation Corrosion Behaviour of AA7075-SiC<sub>p</sub> Composites Fabricated Using Powder Metallurgy and Hot Extrusion

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Abstract—The aim of this study is to investigate the effect of SiC particle size on the hardness, wear and exfoliation corrosion behaviour of AA7075-SiC composites. For this purpose, various size (8, 32 and 82 μm) and amount (wt.%10 and %15) of SiC particles have been added into AA7075 aluminium alloy powders and O35x30 mm cylindrical blocks were produced by pressing. These pressed powder metal compacts are extruded at 480 °C as 12 mm dia round bars. Then, T6 heat treatment was applied to AA7075-SiC<sub>p</sub> composites aged at 120 °C for 24 hours after solution heat treatment at 480 °C for 2 hours. In order to identify the hardness and abrasion strengths, hardness and wear tests were performed to all samples under same conditions. Exfoliation corrosion behaviour of composites was determined using EXCO corrosion test solution prepared according to ASTM G34-Standard test method. Experimental results showed that with the increase of SiC<sub>p</sub> amount in the composites, the hardness and wear resistance increased, but exfoliation corrosion resistance decreased.

Keywords—Include at least 5 keywords or phrases

I. INTRODUCTION

AA7075 alloy have excellent formability in addition to high strength, good corrosion resistance [1] and low density [2]. They are used for high strength structural applications such as aircraft parts and sporting goods [2]. Nevertheless, their applications are sometimes limited because of their low hardness and wear strength. However, these properties can be improved by precipitation and/or introducing second phase particles into the metal matrix [2].

Aluminium matrix composites have the advantage of mixing two or more different materials with opposite properties and are produced by different technological processes such as powder metallurgy [1], stir-casting [3], infiltration[4], extrusion [2]. In aluminium matrix composites, SiC is widely used as a second phase [5–8]. The powder metallurgy method allows the introduction of secondary particles into the base metal matrix in the solid state [2].

The present study is aiming to fabricate the AA7075 aluminium matrix composites reinforced with micro-sized SiC particles by using powder metallurgy and hot-extrusion processes, and investigate their wear and exfoliation corrosion behaviour.

II. EXPERIMENT

AA7075 powders (<74 μm) with chemical composition, presented in Table 1, were blended with different weight (10 wt.% and 15 wt.%) and particle size fractions (8, 32 and 82 μm) of SiC powders (Fig. 1). After blending, the powder mixtures were pressed into a die to form compact shape of 35 mm diameter and 30 mm length under 350 MPa pressure. The compacts were hot-extruded at 480 °C with an extrusion ratio of 8.5:1 as 12 mm diameter round bars (Fig. 2). In order to reduce wall frictional effects, mould release oil was used on the extrusion die surfaces. The extruded rods were cut in lengths of 15 mm. For the T6 heat treatment process, the specimens were solidified at temperature 480 °C for 2 h and quenched in water, then aged at a temperature of 120 °C for 24 h in air.

Table 1 Chemical composition of AA7075 alloy (mass fraction, %)

<table>
<thead>
<tr>
<th>Element</th>
<th>Zn</th>
<th>Mg</th>
<th>Si</th>
<th>Cu</th>
<th>Cr</th>
<th>Mn</th>
<th>Fe</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bal.</td>
<td>4.78</td>
<td>1.84</td>
<td>0.24</td>
<td>1.45</td>
<td>0.25</td>
<td>0.26</td>
<td>0.23</td>
<td>Bal.</td>
</tr>
</tbody>
</table>

Fig. 1 AA7075 alloy and SiC ceramic particles
The structure, morphology and chemical composition analyses of samples were performed using a field emission scanning electron microscope (SEM), (Carl Zeiss Ultra Plus FESEM equipped with EDX). Microhardness measurements were made using a Qness Q250M Macro Hardness Tester employing an indenter of 10 mm diameter and a load of 31.25 kgf on surfaces of polished samples. Each hardness value is the mean value of five measurements. The friction coefficient and wear resistance of specimens were tested using a computer aided pin-on-disc type apparatus (UTS Tribometer T10/20) at the linear sliding speed of 1 m/s under load of 40 N in a sliding distance of 1000 m in dry ambient environment at 24-25 °C with humidity 46 ±2. AISI 52100 steel with 62 HRC hardness was used as counter-disc.

The exfoliation corrosion (EXCO) tests were performed according to ASTM G34-01[9]. The corrosion tests were performed using EXCO solution for different immersion times of 4, 8 and 16 h. The tested temperature was 25 ± 2 °C and the solution-to-sample surface area ratio is 30 ml/cm².

III. RESULTS AND DISCUSSION

Density graph of extruded AA7075 alloy and AA7075-SiC<sub>p</sub> composites were given in Fig. 3. The density of extruded AA 7075 alloy is 2.58 g/cm³ while the relative density is 2.82 g/cm³. This result shows that the samples have about 7% of microporosity. AA7075 alloy have a finely dispersed pore structure, according to its microstructural images (Fig. 4a-b). This figure shows that as the amount of SiC increases, the densification increases. But, when the amount of SiC (for 32 and 82 µm) reached 15 wt%, the densification declines. This is due to the agglomeration of SiC particles during the extrusion process with increasing the SiC percent.

Fig. 3 The variations of density with SiC particle content and size.

As shown in Fig. 4c-h, the porosity content increases as SiC weight fraction increases lead to decrease of porosity. Indeed, the plastic working causes to closing pores during hot extrusion [3]. In addition, it is thought that the hard particles in the matrix structure help to plastic deformation. As a result of increasing plastic deformation, porosity decreased. However, the amount of particles increases above the critical level leads to agglomeration and porosity increases [10, 11]. Also, Fig. 4 shows that SiC particles are finely dispersed in the AA7075 matrix structure.

The influence of SiC particles content and size on hardness is shown in Fig. 5. Considering this figure, by increasing the amount of SiC, composite hardness increases since its hardness is much higher than that of AA7075 alloy [10, 11]. Some other studies report that increasing the amount of hard ceramic particles in the matrix would result in more dislocations that increases the hardness of the composite [12]. Considering Fig. 5 also, it shows that decreasing the particle size will increase the composite hardness. The hardness values of AA7075-SiC
composite samples with 8 and 32 µm are harder than that of AA7075-SiC composite samples with 82 µm particles. This situation is described in two ways. One reason is the greater interfacial area between the hard and soft phases. And the other is that the defects in the coarse-grained particles are more than the fine-grained ones which results in its easy fracture under tension [11].

Weight loss of AA7075 alloy and AA7075-SiC composites as a function of particle content and size at load of 40 N is shown in Fig. 6.

Ceramic particle reinforced AA7075 matrix composite shows better wear behaviour compared to the AA7075 alloy. In the composite samples, the wear rate reduces by the increasing particle content and size. In general, the reduction in wear rate is influenced by the size of reinforcement and volume fraction of reinforcement [13]. It is thought that the reduction of wear rate depending on increasing of particle size is related to contact surface area between particle and matrix. With increasing particle size in the matrix provides more contact surface area and mechanical bonding strength between particle and matrix.

The worn surface images of AA7075 alloy and AA7075-SiC composite samples were given in Fig. 7. As shown in the figures, the worn surfaces consist of long grooves which are the result of abrasive wear mechanism.

After exfoliation corrosion test, the variation of weight loss with corrosion test period, and SiC particle content and size are shown in Fig. 8. Ceramic particle reinforced AA7075 matrix composite shows better corrosion resistance compared to the AA7075 alloy. In the composite samples, the corrosion rate increases by the increasing particle content and size.

It is though that the porous surface of AA 7075 alloy samples causes an increase in the contact surface area between the corrosion solution and sample and it provides corrosion solution to penetrate into the material. Therefore, the corrosion rate in the alloy sample is greater than the composite sample. In the composite samples, the addition of ceramic particles to the matrix decreases the porosity of the composite. Also, the ceramic particles in the matrix cause a decrease in the contact surface area. Therefore, the weight loss caused by corrosion decreases depending on the reduction of surface area exposed to corrosion.
IV. CONCLUSIONS

In the present study, wear and exfoliation corrosion behaviour of AA7075 alloy and AA7075-SiC\(_p\) composites fabricated using powder metallurgy and hot extrusion were investigated. The following results were obtained:

- AA7075 alloy and AA7075-SiC\(_p\) composites were successfully fabricated using powder metallurgy and hot extrusion.
- The density of AA7075 alloy increased with addition of SiC particles.
- By increasing the amount of SiC, composite hardness increases since its hardness is much higher than that of AA7075 alloy.
- The addition of ceramic particles to AA7075 matrix composite shows better wear and exfoliation corrosion behaviours compared to the AA7075 alloy.

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REFERENCES

Modeling of wood bonding strength based on soaking temperature and soaking time by means of artificial neural networks

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Abstract— Adhesive bonding of wood enables sufficient strength and durability to hold wood pieces together and thus produce high quality wood products. However, it is well known that many variables have an important influence on the strength of an adhesive bonding quality. The objective of the present paper is to predict the bonding strength of spruce (Picea orientalis (L.) Link.) and beech (Fagus orientalis Lipsky.) wood joints subjected to soaking by using artificial neural networks. To obtain the data for modeling, beech and spruce samples were subjected to the soaking at different temperatures for different periods of time. In the ANN analysis, 70% of the total experimental data were used to train the network, 15% was used to test the validation of the network, and remaining 15% was used to test the performance of the trained and validated network. A three-layer feedforward back propagation artificial neural network trained by Levenberg–Marquardt learning algorithm was found as the optimum network architecture for the prediction of the bonding strength of soaked wood samples. This architecture could predict wood bonding strength with an acceptable level of the error. Consequently, modeling results demonstrated that artificial neural networks are an efficient and useful modeling tool to predict the bonding strength of wood samples subjected to the soaking for different temperatures and durations.

Keywords— Neural network, bonding strength, prediction, wood, soaking

I. INTRODUCTION

Adhesives allow wood industry to use small dimension wood pieces to produce bigger dimension products, and therefore the strength of the adhesive bonding is of great importance for the wood products [1]. The main role of an adhesive in a product is to transfer the stress from one substrate to another. This means that an adhesive bond needs sufficient durability to hold together the joints produced under different conditions [2]. On the other hand, understanding and controlling the adhesive bonding of wood is a challenging task due to the heterogeneous nature of wood [3].

ANNs are a powerful data modeling method capable of defining complex and nonlinear relationships between input and output parameters related to any processes or systems without the need of any assumptions [4]. In recent years, ANNs have been one of the most attractive fields of the artificial intelligence and has been widely employed in solving the problems such as optimization, classification, prediction and pattern recognition in engineering applications [5], [6]. Unlike traditional modelling approaches, ANNs are capable of learning from examples or training patterns, storing the knowledge in their weights and bias values and use them to predict future values [7]. Due to these advantages, ANNs have been increasingly considered to model the bonding strength of various materials in engineering applications. Taşkın et al. [8] tried the ANN approach to model the bonding characteristics of SiCp reinforced aluminium alloy metal matrix composites. Sancak [9] used the ANN technique for modeling the bonding strength of lightweight concretes. Golafshani et al. [10] modeled the bond strength of spliced steel bars in concrete by means of a ANN. Wang et al. [11] predicted heavy aluminium wire wedge bonding strength by means of the ANN modeling. On the other hand, the use of ANN technique to solve computational problems in wood science has increased rapidly in last two decades. Details of studies carried out to predict wood characteristics with ANN approach were are given as follows. Ceylan [12] modeled drying characteristics of wood by developing a neural network model. Tiryaki et al. [13] employed the ANNs for minimizing the wood surface roughness in machining process. Yang et al. [14] modeled the mechanical properties of heat treated wood using a neural network. In another study, Esteban et al. [15] predicted the modulus of elasticity of wood by an ANN. In another study regarding the strength properties, Tiryaki and Aydin [16] trained a feed-forward ANN to model the compression strength of heat treated wood. Moreover, due to the importance of adhesive bonding of wood and wood products, substantial modeling activities have performed during the last decades with ANN models established with different variables. Ozsahin and Aydin [17] developed an intelligent model which is capable of predicting the optimum veneer drying temperature to ensure a quality bond formation in plywood manufacturing. In another study, Demirkir et al. [18] optimized manufacturing variables for the optimum bonding strength in plywood manufacturing by the ANN modelling. 

With regard to solid wood, Tiryaki et al. [19] used the ANNs to model the optimum bonding strength of wood joints.
subjected to different temperatures and machining conditions. In another study, Tiryaki et al. [20] designed a neural network structure for modeling the influences of amount of adhesive, pressing pressure and its duration on the joining strength. Finally, in the study of Bardak et al. [21], the influences of pressing conditions on the bonding quality of different wood species were predicted by means of a multilayered neural network. These intensive efforts on estimating the bonding strength characteristics revealed that ANNs were quite useful in modeling the bonding characteristics of various engineering materials.

Our purpose in the present modeling study was to predict the bonding performances of wood samples exposed to different soaking temperatures and durations by means of artificial neural network approach, which is one of the soft computing techniques.

II. ARTIFICIAL NEURAL NETWORKS

ANN is computational intelligence method that can cope with complex problems with a capacity to learn by examples. As a robust and versatile modeling tool, ANN has proved to be successful in the solution of various problems in a number of engineering fields [22]. There are different types of ANNs based on the parameters such as neuron configurations and their connection types, and training procedure. Based on a general acceptance, it is possible to say that multilayered perceptron (MLP) trained with the back propagation algorithm is the most popular network structure for engineering applications [23].

The MLP usually comprises an input layer, a few hidden layers and an output layer [24]. The neurons of a MLP network are connected from a layer to the next one by weights \( w_{ji} \). A neuron in any layers of the network gets information \( x_i \) from all the neurons of the previous layer. It gathers information \( \text{net}_j \) weighted by factors corresponding to the connection and the bias \( \theta_j \), and transmits output values \( y_j \) computed by applying an activation function to \( \text{net}_j \) [4]. Fig. 1 defines the general function of a neuron.

![General functioning of an artificial neuron](image)

An ANN needs a training process to perform a desired task. Training is a process of adjusting the connection weights by a learning procedure. After the training process, the network can be employed to make decisions or define associations in new input data sets. It is important to state that the weights gain meaningful information after training whereas they have no meaning before training. For training, the backpropagation is known as one of the most robust algorithms [24]. The details of ANNs are given in Tiryaki and Aydin [16].

III. MODEL DEVELOPMENT STAGES

A. Data collection

The first stage in developing a neural network model is to collect the required data for modeling [25]. In this modeling study, the required data for the intended ANN model were experimentally obtained through soaking experiments carried out under different temperatures and durations. For this purpose, the experimental samples of bonding strength with dimensions of 150 × 20 × 10 mm were thus prepared flawlessly. Fig. 2 represents the dimension of experimental samples of the bonding strength.

![Experimental samples of bonding strength](image)

Ten experimental samples were prepared for each variation in order to ensure the reliability of the measurements. Thus, a total of 320 samples were prepared for four different soaking temperatures, four different soaking durations and two wood species (4 × 4 × 2 × 10). The prepared wood samples were subjected to soaking for different temperatures (20, 40, 60 and 80°C) and durations (10, 20, 30 and 40 min). After soaking process, the wood samples were acclimatized at 20 ± 2 °C and 65 ± 5% relative humidity to achieve a moisture content of 12%. The experiments were performed according to BS EN 205 [26] standards. Eq. (1) was used to calculate the strength values of the experimental samples.

\[
\sigma_y = \frac{F_{\text{max}}}{a \times b} \quad (1)
\]

Where; \( \sigma_y \) gives the value of the bonding strength, \( F_{\text{max}} \) refers maximum load at the break point, \( a \) and \( b \) constants represent the width and length of glued face, respectively.

Following the completion of the experimental procedure, the bonding strength data obtained were grouped into three sub-sets to start the modeling process; training, validation and testing. 70% of all experimental data (twenty-two data) were used for training the intended model. The remaining 30% of the data (ten data) were equally divided for validation (five data) and testing (five data) of the network.

B. Network structure

The detection of the appropriate size of the network in designing a neural network is extremely important. As seen in
Fig. 3, a three-layer ANN structure was determined as the optimum architecture for this study.

A three-layer feedforward ANN model with one hidden layer was constructed and a backpropagation algorithm was used to train network. Levenberg–Marquardt algorithm was selected as learning algorithm in the present study. Each layer of the network is linked to the next layer, but no connections exist among the neurons located within the same layer. The first (input) and third (output) layers of the network include the input variables (wood species, soaking temperature and soaking duration) and output variable (bonding strength), respectively. Since there is no certain rule to decide the number of hidden layer neurons, various combinations were tried in terms of hidden layer numbers and their neurons. After trial and error procedure, best results with minimum errors were obtained with 3-6-1 neuron configuration for input, hidden and output layer, respectively. Here, the important point was to detect the optimal number of hidden layer and its neurons, since the number of input and output layers and their neurons is evident, as discussed above. As shown, the network architecture of the bonding strength prediction model has one hidden layer and six hidden neurons. Already, in the literature, it was reported that one hidden layer is mostly sufficient to solve engineering problems [23], as found sufficient for the present study.

\[
\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (t_i - \hat{t}_i)^2}
\]

(3)

\[
R^2 = 1 - \frac{\sum_{i=1}^{N} (t_i - \hat{t}_i)^2}{\sum_{i=1}^{N} (t_i - \bar{t})^2}
\]

(4)

Where, \(t_i\) is the actual output, \(\hat{t}_i\) is the network output, \(N\) is the number of samples and \(\bar{t}\) is the mean of network outputs.

IV. RESULTS AND DISCUSSION

Table 1 gives the actual values, network output and % errors of the prediction as a result of neural network analysis. As seen from Table 1, in most cases, the ANN predictions are very close to the actual values. In other words, the developed ANN model is capable of giving very near prediction values to actual data of the bonding strength.

<table>
<thead>
<tr>
<th>Soaking temperature duration</th>
<th>Bonding strength (N/mm²)</th>
<th>Beech</th>
<th>Spruce</th>
</tr>
</thead>
<tbody>
<tr>
<td>(°C) (min)</td>
<td></td>
<td>a</td>
<td>p</td>
</tr>
<tr>
<td>20 10</td>
<td>11.008</td>
<td>11.468</td>
<td>-4.179</td>
</tr>
<tr>
<td>20 20</td>
<td>7.704</td>
<td>7.718</td>
<td>-0.182</td>
</tr>
<tr>
<td>20 30</td>
<td>6.312</td>
<td>6.288</td>
<td>0.380</td>
</tr>
<tr>
<td>20 50</td>
<td>5.322</td>
<td>5.356</td>
<td>-0.639</td>
</tr>
<tr>
<td>30 10</td>
<td>4.708</td>
<td>4.738</td>
<td>-0.637</td>
</tr>
<tr>
<td>30 20</td>
<td>4.004</td>
<td>4.083</td>
<td>-1.973</td>
</tr>
<tr>
<td>30 30</td>
<td>2.876</td>
<td>3.051</td>
<td>-6.085</td>
</tr>
<tr>
<td>30 40</td>
<td>3.194</td>
<td>3.237</td>
<td>-1.346</td>
</tr>
<tr>
<td>30 50</td>
<td>2.948</td>
<td>2.774</td>
<td>5.902</td>
</tr>
<tr>
<td>30 60</td>
<td>2.178</td>
<td>2.145</td>
<td>1.515</td>
</tr>
<tr>
<td>40 10</td>
<td>2.186</td>
<td>2.162</td>
<td>1.098</td>
</tr>
<tr>
<td>40 20</td>
<td>1.442</td>
<td>1.613</td>
<td>-11.859</td>
</tr>
<tr>
<td>40 30</td>
<td>0.982</td>
<td>1.057</td>
<td>-7.637</td>
</tr>
<tr>
<td>40 40</td>
<td>0.466</td>
<td>0.495</td>
<td>-6.223</td>
</tr>
</tbody>
</table>

Note: Bold italic data: testing, bold data: validation, the other data: training a, p and e denote actual, predicted and error %, respectively

The performance of the model developed for bonding strength prediction was evaluated. This evaluation was mainly done for both confirming the goodness-of-fit of the model and the prediction accuracy of the bonding strength. As mentioned before, RMSE, MAPE, and \(R^2\) performance measures were considered to assess the performance in making the prediction of the established neural network. In the evaluation process,
the smaller values of the RMSE and MAPE mean the better prediction. On the other hand, with respect to the $R^2$ criterion, better prediction requires higher values.

The criterion of the $R^2$ is widely employed in order to demonstrate the level of the relationship between actual and network outputs. Fig. 4 indicates graphical presentation of the fit between the actual and network outputs of the bonding strength of soaked wood, for training, validation and testing.

The RMSE values were found to be 0.073 for training, 0.325 for validation, and 0.217 for testing. Among evaluation criteria, the MAPE criterion is very critical, and in the literature, many researchers have judged the performance of the model by computing the MAPE [20], [21], [28]. Thus, it was considered to be the primary criterion in terms of prediction accuracy. For the current study, the MAPEs were found to be 2.864% for training, 6.652% for validation, and 6.253% for test. In other words, the MAPEs of the designed model range from 2.864% to 6.652%. These results of the MAPE have demonstrated that the performance of the developed neural network in modeling the bonding strength of soaked wood is adequate. A comparison of the actual and predicted strength values for training, validation and testing stages is provided in Fig. 5.

Fig. 4 The graph of relationship between actual and network outputs of bonding strength: (a) training, (b) validation and (c) testing.

As seen in Fig. 4, the $R^2$ values were found to be 99.92% for training phase, 99.75% for validation phase, and 99.11% for the testing phase in neural network model. These values of the $R^2$ are considered adequate for the bonding strength of soaked wood and thus the developed ANN structure can be employed effectively to make predictions.

Fig. 5 Comparison of actual and ANN prediction, and error values of bonding strength: (a) training, (b) validation and (c) testing.
From Fig. 5, it is possible to see that the predicted values were found to be close to the actual values. In addition, the model outputs generally overlapped with the actual outputs. As expected, the matching of the predicted values and actual values especially in the training data set is excellent. With respect to the comparative graphs of the bonding strength prediction and actual results, it can be said that the established network was successfully trained and exhibited a reasonable accuracy in the prediction of the bonding strength behavior of the soaked wood. These results confirmed that a well-trained ANN is capable of predicting the strength of joints designed under different conditions. Furthermore, as mentioned before, ANNs can describe nonlinear characteristics of the existing variables in the process without any assumptions. It is possible to claim that this flexibility of ANNs makes it more suitable for predicting the bonding characteristics of soaked wood.

V. CONCLUSION

In this study, a feed forward backpropagation network was proposed in order to model the bonding strength of soaked wood. In training period of the network, Levenberg-Marquard learning algorithm was employed. The best prediction results of the ANN were found in the network configuration of 3-6-1. In the proposed model, the values of $R^2$ were over 99% for all data sets, respectively. In addition to the $R^2$, the performance criteria such as the RMSE and MAPE regarding the prediction errors for all data sets were within acceptable ranges. All these show that the learning ability of ANN for estimation is very good and the use of this method may strongly be suggested to eliminate laborious and time consuming experimental investigations. It is possible to say that ANNs are more economical to detect the bonding behavior of the wood soaked under different temperature and durations.

REFERENCES


Friction Welding of AZ91 and 316 L Stainless Steel
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Abstract—316 L stainless steel was provided by private firm. AZ91 alloy was melted under argon atmosphere in a furnace and casted in metal mold. Samples were machined to fit size. Friction welding process was performed for various friction durations under 100 MPa forging pressure and 50 MPa friction pressure at 1000 rpm friction speed for different friction times. Microstructure of welding zone and fractured surface were examined with scanning electron microscopy (SEM). Microstructure studies indicated that welding interfaces were continuous and void-free. The shear strength values of the welding zone and matrix were determined. Fractured surface was examined with scanning electron microscopy.

Keywords—Friction welding, 316 L, magnesium alloy, AZ91, stainless steel.

I. INTRODUCTION

Magnesium alloys have good features such as low density, good damping characteristics, dimensional stability, machinability and low casting costs and hence recently attracted greater attention in academic research and, especially in fields of the aerospace, automobile and electronic industries. To extend the applications of magnesium alloys, the bonding of Mg and other metals is necessary [1-3]. Austenitic stainless steels are noted for their high strength, exceptional toughness, ductility, and formability. They exhibit considerably better corrosion resistance than martensitic or ferritic steels, and they also have excellent strength and oxidation resistance at elevated temperatures [4]. The various fusion and solid-state welding techniques can be applied to these steels. The heat of fusion welding causes grain coarsening in the heat-affected zone and solidification cracking in the weld metal [5].

Recently, many automotive and aerospace components have been produced by using magnesium alloys and austenitic stainless steels. Therefore, the bonding of these dissimilar alloys has become critical for components manufacture. The use of conventional fusion welding methods to join these alloys has limitations due to the distinct differences in their physical and metallurgical properties [6-9]. Friction welding is one of the available joining techniques, and it has been used successively in metals and alloys [10–14]. In the present study, cast AZ91 magnesium alloy and 316 L stainless steel were welded by friction welding and microstructure and mechanical properties of the welded samples were examined.

II. EXPERIMENTAL STUDIES

The alloy AZ91 (Mg–9Al–1Zn) was melted in a graphite crucible in vacuum furnace under argon atmosphere at 750 °C. Then the molten metal was cast into metal molds with 10 mm diameter under protective gas. 316 L stainless steel samples were received a private firm. The samples were machined to 8 mm diameter and 50 mm height.

The friction welding experiments were carried out by a continuous-drive friction welding machine at a constant forging pressure of 100 MPa, forging time of 5 s, and rotational speed of 1000 rpm and different friction times (Table 1). The friction welding process was given schematically in Fig. 1.

![Fig. 1 Schematic illustration of the friction welding process.](image-url)

After welding, the welded samples were cut perpendicular to the welding interface. The surfaces of the welded samples were ground with 1200 grinding paper and polished with 1 µm diamond paste, and then the samples were examined with scanning electron microscopy (SEM). The chemical compositions of the weld zone and the base alloys were determined using energy dispersive spectroscopy (EDS). Shear tests were performed to determine the strength of the weld interface using an electromechanical universal test machine (Shimadzu AG-IS-250) at room temperature. A specially designed specimen holder (Fig. 2) was used to measure the shear strength. Three samples were tested for each welding condition. The fractured surfaces of the welds were observed by SEM.
III. RESULT AND DISCUSSION

Flash formation was observed in all welded samples because of plastic deformation during welding. Friction time plays an important role in the flash formation. More plastic deformation occurs because of the longer the friction time, which produce higher heat in the weld interface. Thus, the burn-off (axial shortening) increases with the increase in plastic deformation (Table 1). The different physical and mechanical properties of the materials exhibit different deformation rates during the friction welding [15].

316 L stainless steel has greater strength at elevated temperatures compared with AZ91. Therefore, 316 L stainless steel shows much less deformation than AZ91 alloy during friction welding and much more mass is transferred to the flash from the AZ91 side.

<table>
<thead>
<tr>
<th>Friction Pressure, MPa</th>
<th>Forging Time, MPa</th>
<th>Friction Time, s</th>
<th>Burn-off, mm</th>
<th>Rotational speed, rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>100</td>
<td>3</td>
<td>1.8</td>
<td>1000</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
<td>5</td>
<td>4.5</td>
<td>1000</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
<td>7</td>
<td>8.2</td>
<td>1000</td>
</tr>
</tbody>
</table>

SEM micrograph of welded samples for 5 s is shown in Fig. 3. It can be clearly observed that a diffusion zone forms at the weld interface for all of the welded samples. The increase in temperature, which depends on the friction time, accelerates the diffusion of atoms. The composition of the diffusion zone of the welded samples was determined by EDS analysis. The analysis shows that the diffusion zone present at the interface consisted of Fe, Al, Cr, Ni, Mg atoms (Fig. 4).

The shear strengths of the welds and the base alloys are shown in Fig. 5. Test results demonstrated that the values of the shear strength of the welded samples increase with increase of friction times. This observation indicates that the increase in the shear strength is related to the magnitude of the accumulated heat input, which depends on the friction time. 3 s friction time was not high enough to produce the required heat for the friction welding, compared with the 5 and 7 s treatment. The shear strength of the sample welded for 5 and 7 s was as high as that of the sample of AZ91 welded.

![Fig. 4 The composition of diffusion zone of the welded sample for 5 s.](image)

![Fig. 5 The shear strengths of the welds and the base alloys.](image)
Fig. 6 shows the SEM fractographs belonging to the AZ91 side and the 316 L side of the welded sample that were treated for 5 s. The SEM and EDS analysis indicated that the failures took place in AZ91 side during the shear test. However, this situation was not observed for all of the welded samples. While the sample welded for 3 s fractured from interface, the samples welded for 5 and 7 s fractured from AZ91 sides. These findings support the trends observed in the shear strength values. The welded samples that have higher shear strengths fail from AZ91.

IV. CONCLUSION

In this study, the friction-welded AZ91 alloy and 316 L stainless steel were free of pores and cracks. Microstructure studies showed the presence of diffusion zone at the weld interface. While the shear strengths of the welds increased with an increase in the process time. A minor variation in the shear strength values was observed between 5 and 7s friction time. The best welding parameter combination was found to be a friction pressure of 50 MPa, and a friction time of 5 s because the axial shortening was minimized.

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REFERENCES

A comparative investigation of the effects of brass and copper electrodes in hole-EDM process

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Abstract

Hole-EDM drilling is a different type of electrical discharge machining (EDM) processes, i.e. sink-EDM and wire-EDM. Although hole-EDM drilling uses the same principles as other EDM methods, a constantly rotated hollow electrode and pumping of dielectric fluid through the electrode tube are the two distinct features. This process has been alternatively used for producing holes in turbine blades, fuel injectors, medical equipment, cutting tool coolant holes, hardened punch ejectors, plastic mould vent holes and wire EDM starter holes. In this study, a comparative investigation of fast hole drilling of die steel, namely as DIN 1.2379 using EDM method was performed in order to explore the influence of electrode material, i.e. brass and copper electrode materials. The comparisons were made from the results of material removal rate (MRR), electrode wear rate (EWR) and scanning electron microscope (SEM) images of the white layer thickness (WLT) taken from the machined hole surfaces. The experimental results reveal that the brass electrode has comparatively better MRR and lower EWR. However, the SEM images show that brass electrode produces less damage and WLT on machined surfaces than copper electrode for this material.

Keywords: Electrical discharge machining, Fast hole drilling, Electrode, Brass, Copper

I. INTRODUCTION

Electrical Discharge Machining is a non-traditional machining process that has become a well-established machining process in manufacturing industries throughout the world and has replaced drilling, milling, grinding and other traditional machining operations. EDM is capable of machining geometrically complex or hard material components that are precise and difficult to machine. EDM processes are classified into die-sinking EDM, Wire-EDM and Hole-EDM. The electrode of die-sinking EDM has the reversed shape of the part to be machined. Wire-EDM uses thin wire, ranging from 0.02 to 0.36 mm in diameter electrode and Hole-EDM uses tabular electrodes have diameter from 0.3 to 6.0 mm.

Drilling small holes is one of the basic metalworking processes; nearly 40% of all production time is spent to produce holes. Conventional drilling techniques cannot be employed to produce small-size holes on difficult-to-cut materials as tool wear/breakage and slow machining rates lead to inaccurate hole dimensions and unacceptable surface quality. The performance of advanced parts such as turbine blades and combustion chambers depend on very large number of small holes for cooling hot components. Typical cooling hole diameters and aspect ratios are in the range of 1–4 mm and 40–200, respectively [1]. Drilling process of small hole, which has the large depth to diameter ratio, is very difficult by using traditional methods. For some materials, which have greater strength and hardness like carbide, tool steel and super alloys, it is nearly impossible. Electrical discharge machining process removes microchips from the workpiece by means of a series of repeated electrical flushing. The EDM process is achieved by applying a succession of discrete discharges between the tool (cathode) and the workpiece (anode), separated by a dielectric fluid. EDM small-hole drilling process is a highly economical method for drilling fast and highly precise holes into all types of conductive materials, either hard or soft [2]. The process is used for production of fuel injectors, venting holes of injection moulds, coolant holes of injection cutting tools, hardened punch ejector holes, wire-EDM starter holes, holes in turbine blades and other similar operations [3] [4] [5].

The most important performance parameters in the EDM process are the surface roughness (Rₐ), the material removal rate, and the electrode wear (EW) [1]. Asperities produced by electrical discharge machining are covered by a multitude of overlapping craters, which results in the formation of corresponding workpiece profiles with a specified accuracy and surface finish, and also white layer (recast layer) is generated in all EDM processes [6]. Eyerciglu et al. [1] reported that the effect of electrical parameters is more significant than the effect of the other parameters on EDM small hole drilling process. Kuppan et al. [7] reported that MRR is affected by duty factor, discharge current and electrode rotation, whereas pulse on-time and discharge current influence the surface roughness value. Singh et al. [8] studied the effect of machining parameters over output performances of ram-EDM of Al-SiC composite and reported that MRR, taper, radial overcut and surface roughness increase while the current and pulse on-time settings were higher. In small-hole EDM drilling, the effects of non-electrical parameters on MRR were researched by Cao et al. [9] Ekmecki et al. [10] studied the effects of pulse energy on geometry and surface damage of the blind holes machined by micro-EDM. Yilmaz and Okka [11] researched the influence of number of channels in the electrodes on performances of small-hole EDM drilling process by using titanium alloys as workpiece material. They reported that the single channel electrode is better than the multi-channel electrode to obtain higher MRR; however, the surface roughness is better when using multi-channel electrode. The effects of input parameters on the response parameters such as average surface roughness (Rₐ) and average
circularity of the drilled holes in nickel-based super alloy was studied by Yadav et al. [12]. Jannamane and Muttamara [13] investigated the influence of EDM parameters on MRR, EWR and tapered hole of martensitic stainless steel AISI 431. The recast layer was much thinner with this oxygen-assisted machining method. Gov [14] investigated that the effects of the dissolved oxygen in the coolant on the hole EDM performance parameters such as material removal, electrode wear, surface roughness, over cut, taper and white layer thickness. The results showed that the increasing in the oxygen dissolution in the coolant, improving the performance parameters. The variations of machining performance outputs were experimentally investigated with the varying machining parameters for metal powder mixed dielectric liquid in EDM by Ėğun et al. [15] it is reported that the type and concentration of the powder in the dielectric fluid and the pulse-on time were effective performance parameters of EDM process. The powder-mixed electrical discharge machining was examined using SiC powder mixing in water dielectric liquid by Ekmekeci et al. [16]. The experimental studies revealed that the surface morphology drastically affected the additives as means of secondary discharges and particle migration from dielectric liquid. In this study, electro discharge hole drilling processes was applied to DIN 1.2379 tool steel by using single channel brass and copper electrodes. In the study the electro erosion parameters ($T_{on}$, $T_{off}$ and C) kept constant and the effect of the current and electrode materials on the performance parameters such as material removal rate, electrode wear rate and the SEM images of the white layer thickness was examined.

II. MATERIALS AND METHOD

Experiments were performed by using JS EDM AD-20 type hole electrical discharge machine which is available in Mechanical Engineering Department of Gaziantep University. The samples were prepared by 10×10×40 mm DIN 1.2379 die steel which were cut by wire electro discharge machining. Each face of the samples was ground by using 320 to 2000 size emery papers gradually and polished by using 1 µm diamond suspension before drilling. Single channel 2 mm diameter brass and copper electrodes were used for drilling the holes which were drilled on the centre of the machined polished faces vertically (Fig. 1). The major electrode material properties are given in Table II. Experiments were performed in 3 repetitions and the performance parameters were defined by average of these three measurements. The EDM parameters; current (I), arc on time ($T_{on}$), arc off time ($T_{off}$), and capacitance (C) were chosen as the optimum values which were proposed by Eyericioğlu et al. [1] The list of the EDM parameters are given in Table I.

Table I. Properties of the Electrode Material

<table>
<thead>
<tr>
<th>Electrode Material</th>
<th>Copper</th>
<th>Brass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting point (°C)</td>
<td>1084</td>
<td>900-940</td>
</tr>
<tr>
<td>Electrical resistivity (ohm-cm)</td>
<td>1.69</td>
<td>4.70</td>
</tr>
<tr>
<td>Thermal conductivity (W/m·°K)</td>
<td>391</td>
<td>159</td>
</tr>
<tr>
<td>Specific heat capacity (J/g·°C)</td>
<td>0.385</td>
<td>0.380</td>
</tr>
</tbody>
</table>

Table II. Experiment Parameters

<table>
<thead>
<tr>
<th>Fixed parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time on, $T_{on}$ (µs)</td>
<td>30</td>
</tr>
<tr>
<td>Time off, $T_{off}$ (µs)</td>
<td>10</td>
</tr>
<tr>
<td>Capacitance C (µF)</td>
<td>1422</td>
</tr>
<tr>
<td>Voltage (volt)</td>
<td>30</td>
</tr>
<tr>
<td>Electrode rotation speed (rpm)</td>
<td>200</td>
</tr>
<tr>
<td>Coolant pressure (bar)</td>
<td>100</td>
</tr>
<tr>
<td>Electrode polarity</td>
<td>Negative (-)</td>
</tr>
</tbody>
</table>

Variable parameters

<table>
<thead>
<tr>
<th>Electrode type</th>
<th>Current, I (Ampere)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass, Copper</td>
<td>10,11,12</td>
</tr>
</tbody>
</table>

In this study, the performance parameters are defined as material removal rate (MRR), electrode wear rate (EWR) and the SEM images of the white layer thickness (WLT) of the workpiece surface.

A. Material Removal Rate

EDM is defined as the high-energy sparks that occur between the workpiece and electrode cause material removal and evaporation. In EDM process, the material removal rate is defined as the amount of material removal at unit time. In EDM process high MRR is intended and the studies are performed at this situation. In this study, the specimens were weighed before and after the experiments by using 0.1 mg sensitive Shimadzu AUX220 digital balance. The machining time was measured by using digital stopwatch. And the machining speed was calculated by equation (1).

\[
MRR \left( \frac{mg}{min} \right) = \frac{\text{initial weight} - \text{final weight}}{\text{Machining time}} \tag{1}
\]

B. Electrode wear rate

In EDM process, high temperature sparks provide the chip removal from the workpiece at the same time these sparks erode the electrode. This erosion is known as electrode wear in EDM process. In EDM drilling process, machined geometry is directly related to the electrode wear, so the minimum electrode wear gives better geometric performance on workpiece. In this study, the electrodes were weighed before and after the machining by 0.1 mg precision digital balance. And the electrode wear was calculated by using equation (2).

\[
EWR \left( \frac{mg}{min} \right) = \frac{\text{initial weight} - \text{final weight}}{\text{machining time}} \tag{2}
\]
C. SEM Images of White Layer

In all types of EDM processes, white layer is generated, related to the high electrical discharge that is caused by the high temperature generation and sudden cooling between the workpiece and electrode. This white layer has the very hard and brittle properties. Thermal stresses are generated in the white layer and it causes the micro cracks which lays from white layer to main material [17]. These micro cracks tend to develop from the white layer to main material and they decrease the fatigue strength and service life of the part [17]. In this experimental study, the cross sectional SEM images were taken by using Jeol JSM-6390 LV electron microscope and the white layer thickness were measured by using these images.

III. EXPERIMENTAL RESULTS

D. Material Removal Rate

In this study, two types of tubular electrodes were used. The effects of electrodes and current on MRR for DIN 1.2379 die steel are presented in Fig. 2. When material removal rate is considered according to the current, the MRR is decreased as the current increased for both electrode types. The better MRR was obtained at 10 A current value. When MRR of the electrode types are compared, brass electrode has the best MRR than the copper for all current levels. As in the case of copper, material removal rate is lower than that of the brass. This might be due to melting temperature of copper electrode (1084 ºC) which is higher than that of the brass electrode (900 ºC). It is obvious that copper has higher thermal conductivity (391 W/m.K) and less electrical resistivity than brass (159 W/m.K). Thus, the discharge energy produced while EDM machining has profound effect on brass in terms of higher MRR.

Moreover, although copper material has less electrical resistivity and higher melting temperature than brass alloy, the MRR results show that brass electrodes would be more preferable in terms of having higher MRR. It is to be the reason of that comparatively low thermal conductivity of brass as an electrode material does not allow the absorption of much of the heat energy, and the most heat is utilized in removal of material from the workpiece of low melting temperature [18].

E. Electrode Wear Rate

In EDM process, high energetic electrical spark erodes the workpiece and picks off the particles from the workpiece surface nonetheless it erodes the electrode and picks off the particles from the electrode respectively. Normally, electrode wear is related to the electrical parameters of the EDM process. In this study, the electrical parameters of $t_{on}$, $t_{off}$ and capacitance (C) were taken constant and the effect of the current and electrode materials on the electrode wear rate was examined. Electrode wear is mostly depending on the electrode materials and energy of discharge among the other factors such as pulse duration/interval, polarity, dielectric etc. [19]. When the EWR results are examined, Fig. 3 clearly shows that the material removal of copper is in lower rates than that of brass electrode for all current values. Brass electrode undergo lower electrode wears compared to the copper electrode. Since copper has higher melting point and thermal conductivity than that of brass. Also, higher MRR rates that cause lower EWR. Therefore, brass electrode can be used in order to consume less amount of electrode compared to copper electrode material.

F. White Layer Thickness

Through the EDM drilling of holes, recast layers were generated at the side wall of each hole. The recast layer thickness at the wall of the hole was measured since it is the surface subjected to continuous machining throughout the hole drilling process. SEM images of the EDM drilled surfaces were taken in order to compare the effects of the electrode material on white layer of workpiece surface. From the examination of the surface characteristics, it was observed that EDM fast hole drilling process produces globules, debris, pockmarks, melted drops, varying size craters on surface.

To ensure that the recast layer thickness measured was representative of the entire recast layer, a 400 µm sample length of recast layer thickness was extracted for measurement. Furthermore, as recast layer thickness was not uniform throughout the sample length, a representative average recast layer thickness was determined. It is seen in Fig. 4, white layer thicknesses of the EDM drilled holes were changing from 11 µm to 19 µm from 10 A to 12 A, respectively. The reduction in WLT is about 40% for 10 A current value comparing to 12 A. Also, the white layer creation is less for brass electrode compared to the copper electrode. It was observed from the Fig. 5, white layer, melted drops, craters and cracks are more
pronounced when using copper electrode. This also makes the surface rough and having uneven surface profile.

IV. CONCLUSIONS

The outcomes of this study can be concluded as:

- Nearly 20 percent decrease in MRR has been achieved by using the brass electrode. This provides a significant improvement of the machining time for EDM drilled deep holes.
- MRR is decreased as the current increased for both electrode types. The better MRR was obtained at 10 A and brass electrode.
- Electrode wear rate is reduced approximately 12% by using brass electrode. This means reduction in electrode cost. (i.e., manufacturing cost).
- EWR is decreased as the current increased for both electrode types. The better EWR was obtained at 12 A and brass electrode.
- It can be expected that the service life and fatigue strength of the workpiece will be improved by decreasing the white layer thickness.

V. REFERENCES

Steel AISI 431 by EDM using brass tube electrode.


Discharge diamond drilling of nickel-based superalloy aerospace material.


Investigation of the Process Parameters of Sheet Metal Blanking Process by Using Finite Element Method

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Abstract— Blanking process has an important usage in manufacturing and has become a necessity in several major sectors like automotive, sheet metal forming industry and etc. Although the general aspects of blanking seem simple, the shearing mechanisms and the governing parameters have a complex relationship and directly affect the surface quality of the blanked part. Also the lack of prediction capabilities in experimental studies leads to time, money and labour consuming trial and error procedures. Usage of FEM based programs to simulate blanking to obtain numerical results and observe the shearing mechanism is a cheap and a detailed way for industrial applications. In this study five different clearances (%1, %3, %5, %10 and %20) and two different thicknesses (t:2 and t:3) were used to simulate the blanking process. Simulations were executed by using the FEM program, Deform 2-D. Investigations were made on the parameters related to crack progression like indentation angle, rollover angle and depth, crack initiation and crack propagation angles. The results of the present paper are in agreement with the results of experimental studies.

Keywords— Blanking process, Sheet metal, Process parameters, Shearing mechanisms.

I. INTRODUCTION

Blanking is an effective process in sheet metal processing industry; but as in every production cycle, blanking process has a downside which is; generally, a subsequent deburring is required after blanking so that the processing time and labor costs are increased. Elimination of burr formation may eliminate the final finishing process totally and therefore the cost. The overall goal is to improve the blanked parts surface quality in such a way that the produced part does not need to be reworked.

In blanking, although the process seems simple, achieving a good surface quality relies on many parameters. Clearance which is the most effective parameter, material type, material thickness, shape of the component, tool geometry and many other parameters are directly in conjunction with each other [1]. This is the reason that makes blanking a complex and a difficult process to predict. This lack of prediction leads to time, money and labour consuming trial and error procedures, especially for experimental studies.

As an alternative approach, usage of FEM based programs to simulate blanking for obtaining numerical results and observing the shearing mechanism is a cheap and a detailed way for industrial applications.

For many years, researchers have been trying to model the blanking process by using FEM approaches. Some models tried to assess the parameters like; clearance, friction and mesh adaptivity [2, 3]. But these studies didn’t take the sheared edge formation into the account which is highly necessary to be predicted. In order to improve this gap, new approaches have been developed. Faura et al [4], tried to predict optimum clearance by presenting crack propagation angles throughout the sheared edge. Hambl et al, studied the same concept and also integrated neural networks to predict burr heights and to optimize the blanking process [5, 6, 7]. However, the results especially the optimum clearance value was given more than %10 which is so high to obtain a good surface quality. Prediction of burr formation [8, 9, 10] and sheared edge quality [11, 12, 13] in blanking have been investigated also by other researchers. They used different programs and behaviour laws to predict the ductile fracture phenomenon in blanking. As a result, the general acceptance is that if a good surface quality is desired, clearance value has to be %5, if low blanking forces are desired, clearance has to be at least %10 and above. Hereby, they stated that it’s up to the practitioner’s choice between quality and energy efficiency.

In this study, to observe the claims stated by previous researchers; five different clearances (%1, %3, %5, %10 and %20) and two different thicknesses (t:2 and t:3) were used to simulate the blanking process. Simulation were executed by using the FEM program, Deform 2-D. Investigations were made on the parameters related to crack progression like indentation angle, rollover angle and depth, crack initiation and crack propagation angles.

II. PROCESS PARAMETERS

A. Ideal Cutting Condition

The ideal cutting condition is where the punch load is the lowest for energy conservation and the quality of the blanked part is so good that no extra labour is needed to correct the defects on the blanked part surfaces.

Good surface quality depends on the deformation path of the shear zone which is directly affected by the clearance.
blanking process, clearance \(c\) is taken as a percentage of the sheet thickness and defined by:

\[
\frac{100(D_m - D_p)}{2t} \text{(\%)}
\]

(1)

Where \(D_m\) is the lower die diameter, \(D_p\) is the punch diameter and \(t\) is the thickness of the strip material.

The ideal cutting condition is achieved when the angle \((\beta)\) which is the angle of real crack propagation direction and angle \((\theta)\) which is the angle of ideal crack propagation direction coincides with each other. If this condition can be procured, the blanked part has burr free surfaces.

If the crack propagations don’t coincide, secondary crack formation occurs that creates lower surface quality. The directions of angle \((\beta)\) and angle \((\theta)\) were illustrated in Figure 1. As can be seen, real crack propagation direction doesn’t coincide with the ideal crack propagation direction, creating secondary cracks. The equalization of ideal crack propagation angle \((\theta)\) and the angle of the direction of crack propagation \((\beta)\) giving the ideal cutting condition can be expressed as:

\[
\Phi = \beta - \theta \cong 0
\]

(2)

The ideal crack propagation angle can be expressed by [5]:

\[\theta = \arctan \left( \frac{c}{t - u_p} \right)\]

(3)

Where \(c\) is the clearance; \(t\) is the sheet metal (workpiece) thickness and \(u_p\) is the punch penetration corresponding to the first crack initiation within the sheet.

During the blanking process, shearing of the workpiece happens in a narrow zone called the shear band. The stress and effective strain are defined as \(\sigma\) and \(\varepsilon\).

Fracture criterion was chosen Normalized Cockroft and Latham. The criterion states that the fracture occurs when the effective strain reaches the critical value expressed as:

\[
\int_0^f \left( \frac{\sigma^*}{\sigma} \right) d\varepsilon = C
\]

(4)

where \(\sigma^*\) is the maximum principal tensile stress, \(\varepsilon^*\) the fracture strain and \(C\) is the critical value. The effective stress and effective strain are defined as \(\bar{\sigma}\) and \(\bar{\varepsilon}\).

During the blanking process, shearing of the workpiece happens in a narrow zone called the shear band. The stress ratio \(\frac{\sigma^*}{\sigma}\) is assumed to be constant throughout that band where the deformation is highly concentrated. Therefore this assumption may be implemented into Cockroft and Latham criterion and approximated by \(\varepsilon^* = C^*\) at the shear band. This approach postulates that a crack initiation occurs at the point of the sheet whose effective strain first reaches the fracture strain of the work material [4]. The program uses element deletion method to iterate the meshing procedure and deletes an element when the critical values are satisfied. But element deletion may cause volume degradation and lead to miscalculations. To prevent and limit this situation, a very fine
mesh has to be used where a probable fracture occurrence is expected. To achieve a very dense mesh, 10000 isoparametric quadratic elements were used as the element meshes of the sheet. The geometrical model of the blanking process and the FEM meshes of the workpiece can be seen in Figure 3.

![Image of mesh and FEM meshes](image.png)

Fig. 3. The geometrical model of the blanking process and the FEM meshes of the workpiece.

**D. Experimental setup**

The front view of the designed die and its components were given in Figure 4. The die consists of six components; upper die block (1), punch holder (2), punch (3), fixed stripper (4), lower die (5) and lower die block (6).

The upper die block, punch holder, fixed stripper and lower die block were made of St 37 steel whereas the guide rods on the upper die block, punch and lower die were made of heat treated AISI 4140 for long durability.

All experiments were made by a hydraulic press which had adjustable speed and loading capabilities.

![Image of experimental setup](image.png)

Fig. 4. The front view of the designed die for experiments.

**E. Material Model and Experimental Parameters**

AISI 304 stainless steel was used for both simulation and experimental studies. AISI 304 is a very common type of stainless steel used in different kinds of industrial applications. AISI 304’s usage areas can vary from simple hypodermic needles to moderate applications like marine industry and heavy industry zones like nuclear plants [14].

Mechanical properties of AISI 304 were given in Table 1.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, Ultimate</td>
<td>505 MPa</td>
</tr>
<tr>
<td>Tensile Strength, Yield</td>
<td>215 MPa</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>70 %</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>193 - 200 GPa</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
<td>0.29</td>
</tr>
<tr>
<td>Charpy Impact</td>
<td>325 J</td>
</tr>
<tr>
<td>Shear Modulus</td>
<td>86 GPa</td>
</tr>
</tbody>
</table>

Sheet thickness was taken as t=2 mm and t=3 mm, die diameter as 10 mm and clearances were taken as %1, %3, %5, %10 and %20 for all experiments. Velocity and loading had been kept constant for all simulations and 12 tons at constant speed of 0.01 m/s were used to execute the blanking processes.

**III. RESULTS AND DISCUSSION**

The microscopic image of a blanked part and the image taken from Deform program were given in Figure 5. As can be seen that crack propagations and related zones are similar between experimental and simulation results. The numerical values gathered from experiments and simulations (Punch load, stroke, blanking energy, etc.) are also similar. Blanking energy difference between simulation and real experimental values were given in Figure 6.

![Image of microscopic and simulation images](image.png)

Fig. 5. The microscopic image and the simulation image of a blanked part (t=2 mm, clearance: %5).

![Image of energy change](image.png)

Fig. 6. Blanking energy change for simulation and real experiments. According to clearances.
A. Crack Propagation Angles

The difference between real crack propagation angle (β) and ideal crack propagation angle (θ) was calculated according to Φ=β−θ condition. The condition postulates that the closer Φ to zero, cleaner the blanked surface. The differences (Φ) according to clearances for t=2 mm and t=3 mm were given in Figure 7.

The results showed that workpiece thickness had an effect on crack propagation. The closer values to zero were found when the clearance was %3 for t=2 mm and %5 for t=3 mm. Also, as the clearance increased, the difference between real crack propagation angle (β) and ideal crack propagation angle (θ) increased which resulted in low surface quality. (+) and (−) values mean that the real crack propagation followed a direction below ideal crack propagation direction when the value was (+) or real crack propagation followed a direction over ideal crack propagation direction when the value was (−).

In previous researches [4, 15], it was suggested that the ideal clearance is between %10 and %12 for AISI 304 and t=1 mm which is highly unlikely because as the thickness increases, the clearance increases for ideal cutting condition. They also claimed that real crack propagation angle (β) remains nearly constant for all clearance values and only ideal crack propagation angle (θ) changes. Results showed that θ has to increase with increasing clearance because Formula 3 is the representation of a geometrical aspect but β also increases with increasing clearance. The only difference is the path that β follows (below or top of θ) with changing clearance.

As can be seen from Figure 8, indentation angle (α) was the lowest at %3 clearance for t=2 mm and the lowest at %5 clearance for t=3 mm which are in agreement with results found concerning crack angles.

B. Indentation Angle

Indentation angles (α) change for t=2 mm and t=3 mm according to different clearances were given in Figure 8.

Indentation angle (α) with a small value is important to achieve a good surface quality because it is the value of how the blanked part gets bent from cutting edges through its middle section on the upper portion. In case of too tight clearance (1%), indentation angle (α) increases because of the high punch loading. The behavior is same with loose clearance (10% and more) because the distance increases between punch and die’s cutting edges. In both cases the workpiece bends more.

C. Rollover Depth and Rollover Angle

Rollover is the bending of the lower portion of the blanked part due to the pulled materials into die cavity. In a blanking process, creation of rollover is not a desired situation. Results show that there is a connection between indentation angle (α), rollover depth (Rs) and rollover angle (Ra).

Rollover angle is directly affected by rollover depth and indentation angle. Rollover angle increases or decreases with rollover depth’s behavior. In case of too tight clearance (%1), high punching load tries to bend the edge of the blanked part for more rollover. Rollover depth behavior to that exerted force is less than expected because there is a little gap between die cavity. However it’s still higher than rollover depth created by %3 and %5 clearances. For clearances more than %10, although the punching load is much lower, more material is pulled between the die cavity that results in the increase of rollover depth. This also increases rollover angle.

If indentation angle increases which means more bending of the upper portion, the lower portion of the workpiece also bends outwards. This bending also increases the rollover angle. The opposite is also valid.

In Figure 9 and 10, it can be observed that rollover angle and depth is minimum at %3 clearance for t=2 mm thickness and minimum at %5 clearance for t= 3 mm thickness. These results are in correlation with indentation angle and ideal crack parameters.
IV. CONCLUSION

Blanking of an AISI 304 workpiece with two thicknesses (t=2 mm and t=3 mm) was executed for this study. Five different clearances (%1, %3, %5, %10 and %20) were used to achieve blanks with 10 mm diameter. behaviours of crack propagation angles, indentation angles, rollover angles and rollover depths were observed. Results can be summarized as below:

- Clearance has a very important necessity in blanking process. All blanking parameters are dramatically altered with changing clearance.

- The optimal clearance value where the surface quality is greatest that creates the ideal cutting condition is dependent on the material kind and thickness. In this study, all parameters became aligned with each other at %3 clearance for t=2 mm and %5 clearance for t=3 mm. But, claiming that the optimal clearance is between %3 and %5 for all kinds of materials is highly unlikely. However, it’s observed that %10 clearance doesn’t have any good result in surface quality and also in blanking energy which some researchers suggested the opposite.

- Too tight and too loose clearances, also give low surface quality, but as mentioned, it’s dependent on the material type and should be investigated.

- As the material gets thicker, all process parameters have tendency to increase.

- Indentation angle (α), rollover depth (Rd) and rollover angle (Re) have a close relationship with each other which are also driven by the change in clearance. It can be stated that the ideal cutting condition on a blanked part can be achieved at a clearance where the crack propagations are towards each other, has minimal indentation angle, has minimal rollover depth, has minimal rollover angle and has minimal blanking energy.

REFERENCES


Meso/Miniature Forming With Flexible Die

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Abstract—In recent years, demand of meso/miniature scale sheet metal part with different geometry has increased dramatically. Pins for IC-carriers, fasteners, micro screws, lead frames, micro-cups and connectors, cell phones parts, as well as medical implants are the typical examples of these parts. In sheet metal forming processes, the geometry of the formed part follows the geometry of the die. Sheet metal forming can be divided as rigid die and flexible die according to die material. Flexible-die forming process is a versatile metal fabrication process is used in commercial aerospace, automotive and military applications. This process uses a flexible pressure carrying medium to replace a rigid punch or die. In forming process flexible material has different roles on forming the metal parts such as a punch, or for tube bulge forming etc. In this study, forming processes requires only a single rigid tool half and polyurethane with different hardness is used as flexible material and experimental data from forming operations are presented briefly.

Keywords—Sheet Forming, Miniature Forming, Flexible Die, Formability, Meso-scale forming.

I. INTRODUCTION

Sheet metal forming processes are the one of the main manufacturing processes and widely used to produce complex parts. Some developments introduced in metal forming processes during the last 50 years. These developments include the use of unusual tools like those using high hydraulic pressure fluid, flexible tools. Flexible tool using in metal forming is a new process to produce sheet metal parts with complex shapes by flexible pressure carrying medium, such as rubber or polyurethane, as a die. Main advantages of flexible forming are low cost tooling, protection of surface of the metal in contact with the flexible tool from scratches, variability of process.

Rubber forming had its onset in the last part of the 19th century, as in [1]. In this review, several processes are individuated: the Guerin process (which used an enclosed rubber pad), the Marform process (with addition of an independent blank-holder), the Verson-Wheelon process (which used a comparatively lighter press with an inflatable rubber bag), bending, sheet metal drawing embossing, blanking and piercing, and bulging are performed using flexible tools. Also, urethanes were considered the best materials for flexible tools because of their good oil and solvent resistance, good wear resistance, high thermal stability and load-bearing capacity. Aluminum sheet forming was studied by using flexible die made of neoprene or commercial rubber, as in [2]. They concluded that flexible forming is capable of producing, from thin aluminum alloy sheet, shallow formed parts with good surface finish and little metal thinning. Tooling costs are reduced considerably as only one shape block to be manufactured per component. In addition, time of production is low because of versatility of flexible material. Several techniques that were recently developed and utilized to fabricate sheet metal parts in macro scale, as in [3]. In this review, the urethane has different roles in these techniques on forming the metal parts that are: 1) as a punch, 2) as a clamp, 3) for tube bulge forming, 4) for creating blanking-holding force in deep drawing, 5) as a soft and flexible male punch for redrawing and reverse drawing. The influence of grain size effects on micro channel forming was studied in [4]. In this study, aluminum sheets that are annealed with different temperature and polyurethane with different hardness values are used. They concluded that annealed at a higher temperature sheets has better formability. It has been found the softer polyurethane can form the micro channel deeper.

Scales for processes and materials are generally classified as nanoscale (<100 nm), microscale (100 nm to 100 µm), mesoscale (100 µm to 10 mm) and macroscale (>10 mm). A comprehensive summary of the recent state-of-the-art for Micro/Meso Mechanical Manufacturing (M³) is given in the NSF workshop report [5]. Meso scale manufacturing has wide application areas. Biotechnology, medicine, avionics, communications are some of these areas. Specifically, mechanical watches, small motors and bearings, lenses for cameras and other parts of cell phones, mesoscale fuel cells, biomedical implants, mesoscale molds and many others [6]. In this study, flexible forming of Al 1050 aluminum sheet with 1 mm thickness is investigated. In particular, metal to metal contact die and metal to flexible contact die is compared in case of forming failures. As flexible material polyurethane with two different hardness values are used to form simple shapes.

II. METHODS AND PREPARATION

A. The Rigid Dies

One type rigid dies were used in experimentation, as shown in Fig. 1. It is used to form spherical geometry. Punch has 7.5 mm radius tip and female die has a gap which has 35 mm
diameter and 16 mm depth, as shown in Fig. 2. To produce backward force to punch, spring with 0.6 N/mm of stiffness was used. All rigid dies were made from specimen plain carbon steel (AISI 1020).

and diameter of the polyurethane were 16 mm and 35 mm respectively.

B. The Flexible Materials

Polyurethane with 20A and 40A hardness, as shown in Fig. 3, was used as a female die for this study of which the mechanical properties [7] can be found in Table I. The height

<table>
<thead>
<tr>
<th>Polyurethane hardness</th>
<th>Tensile Strength(MPa)</th>
<th>100% Modulus(MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20A</td>
<td>2.62</td>
<td>0.552</td>
</tr>
<tr>
<td>40A</td>
<td>5.86</td>
<td>1.14</td>
</tr>
</tbody>
</table>

C. The Aluminium Sheet

A thin aluminium sheet, Al 1050, with thickness of 1 mm was used for forming test. Tensile test were conducted on dog-bone shaped specimens in SHIMADZU AG-X machine. The specimens were 175 mm length and 30 mm wide with 50 mm gauge length. Test was carried out 1 mm/min of rate. The aspect of some specimens after tensile test is shown in Fig. 4. The stress-strain graph of test is shown in Fig. 5. The yield strength of 90±5 MPa was measured along longitudinal direction.
Forming process was carried out in two ways on SHIMADZU AG-X machine. In first way metal to metal contact forming was applied, flexible material was not used. In second way flexible forming was carried out by means of the Guerin process. The flexibility of the process and its capability of drawing relatively complex parts, the protection of the workpiece surface by flexible rubber and its low tooling costs are some of the advantages of this process. Aluminum blanks was cut from sheet with 44 mm diameter by using TRUMPF 4002 laser cutting machine. In flexible forming, flexible material was put in female die gap and forming process was conducted as shown in Fig. 6. All forming tests were carried out at 1 mm/s.

III. EXPERIMENTAL RESULTS AND DISCUSSION

A. Metal to Metal Contact Forming

In this case effect of depth of penetration was evaluated by using five different penetrations (4, 6, 8, 9, 10 mm). By increasing penetrations during forming, several failures were observed especially tearing of sheet near the contact area of punch tip and sheet. Fig. 7 shows occurrence of tearing and effect of penetration to formed profiles.

These distances were measured by KEMCO Fanamation CMM machine. In 9 and 10 mm penetration experiment, nearly at 17 mm of distance tearing was observed.

B. Metal to Flexible Material Forming

20A hardness polyurethane was put in female die gap. When punch force is applied on polyurethane, it has elastic deformation consisting of two parts: one deforming to die cavity and the other generating the binder force on the flat portion of the die. Six different penetrations (4, 6, 8, 8.5, 9.5, 10 mm) were applied to specimens. Effect of flexible material to sheet profile is shown in Fig. 8.
40A hardness polyurethane was conducted same as 20a flexible material. Effect of 40A flexible material to sheet profile is shown in Fig. 9.

In all forming types, tearing was observed at 10 mm penetration. It is obvious that sheet profile by formed 20A polyurethane are higher than 40A, Figs. 10, 11 and 12 shows the aspect of specimens after forming in metal to metal contact forming with 9 mm penetration, metal to 20A polyurethane forming with 9.5 mm penetration and metal to 40A polyurethane forming with 9.5 mm penetration. Also figure Fig. 13 shows the comparison of these sheet profiles after forming operation.

Softer polyurethane can provide to deform the sheet into die cavity better than the harder polyurethane since elastic deformation of softer polyurethane is bigger than harder one that could cause the sheet to be deformed into die cavity when the same condition applied. Figs. 13, 14 and 15 shows the first three penetrations (4, 6, 8 mm) for all forming operations.
IV. CONCLUSION

In this study, series of experiments were conducted on Al 1050 with 1 mm thickness to investigate the flexible material on forming process. As a die material, effect of polyurethane hardness has been discussed. So;

- Formability of sheet has been increased in in flexible forming with appropriate flexible material.
- Softer polyurethane contacts the material surface more than harder one. Due to this condition, load distribution on material surface becomes more uniform and this causes more uniform deformation.

REFERENCES

Tensile and flexural behavior of nano-silica modified carbon/Kevlar hybrid composites

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Abstract—The purpose of this article is to investigate the effect of different particle contents of nano-silica on the tensile and flexural properties of intralaminar carbon/Kevlar hybrid composites. Twill 2/2 woven carbon/Kevlar fiber was used as reinforced fiber with epoxy resin. Five weight fractions (0.5%, 1%, 1.5%, 2.5% and 3%) were used for production of laminated composites. Then, test samples were produced according to ASTM standards. Results showed that addition of nano-silica to carbon/Kevlar composite increased the tensile and flexural strength. Nano-silica contents of 3 wt% gave the highest tensile strength and 1.5 wt% gave the highest flexural strength among the other ratios.

Keywords—Carbon/Kevlar fiber, nano-silica, hybrid composite.

I. INTRODUCTION

In recently years, the applications of polymer composites have been increased and that attributed to mechanical properties improvement by adding high strength fibers to brittle matrix. Furthermore, this improvement may be increased with using rigid inorganic particulate filler within polymer matrix, which leads to increase the applications of polymer base composites. These applications can be very useful such as medical industries, renewable energy application, automobile, aviation and aerospace. Some researchers [1, 2] toughened epoxy matrix by incorporating thermoplastics and rubber particles. Both of them cause mixture viscosity elevation after mixing with epoxy resin, which lead to difficulties in lamination process and thus decreasing in modulus and strength values. Therefore, using rigid particle can improve the mechanical properties of composite. Marjetka and conradi [3] concluded that the filled of a polymer matrix with nano-silica particles gives significant increase in the modulus and strength of the matrix to the overall composite properties. Alsaadi and Erklig [4] also reported similar findings, such that the maximum improvement of tensile strength, tensile modulus, flexural modulus and flexural strength were improved by 17.8% for the 17.8%, 11.3%, 32.0% and 36.4% at nano-silica particle content of 1.0 wt% compared to unfilled polymer composite. Jumahata et al. [5] studied the effect of nano-silica with 5–25 wt% particle content on the tensile stress-strain results of epoxy A 40 wt% nano-silica/epoxy. They found that the incorporation of a well-disperse nano-silica improved the tensile modulus and strength of about 38% and 24%, respectively. Singh et al. [6] presented a review of the kevlar fiber characterizations. They indicated that the anisotropic nature of the Kevlar fiber was due to its unique properties such as higher strength to mass ratio and modulus. Manjunatha [7] examined the tensile and fatigue behavior of nano-silica particles modified glass fiber reinforced epoxy (GFRP) composite, the tensile strength increased by about 19% and 5%, whereas the modulus increased by about 17% and 7% in the bulk epoxy and GFRP composite. Ferreira et al. [8] reported that the addition of nano clays within woven bidirectional Kevlar fabric/epoxy composites reduced the strength and increased the stiffness of the composite in both tension and bend loading, respectively. Dong et al. [9] studied the flexural behavior of hybrid composites reinforced by S-2 glass and T700S carbon fibers in an intra-ply configuration. The specimens were manufactured using the hand lay-up process and tested in a three-point bend configuration. It was shown that, utilization of intra-ply hybridization could improve the flexural strength and flexural modulus. Pincheira et al. [10] investigated the effects of aramid fibers contribution on mechanical properties of a twill weave hybrid carbon–aramid fiber reinforce epoxy composite. They concluded that the presence of aramid fiber presents a more ductile response with respect to the carbon reinforcement. Woo and Kim [11] studied the high strain-rate failure characteristics of the carbon/Kevlar hybrid composite that subjected to compressive loading. They found the failure process of the carbon/Kevlar hybrid woven composite showed initial matrix fracture and then brittle carbon fiber breakage. Subsequently, multiple failure mechanisms appeared, such as fiber-matrix debonding, fiber pull-out, excessive deformation and breakage in the Kevlar fiber tips including splitting and fibrillation. Wan et al. [12] used the two-step surface treated carbon/Kevlar hybrid fibers-reinforced composite with varying fiber–matrix interfacial bonding to show a positive hybrid effect on flexural strength, indicating the existence of hybrid effect is related to the nature of fiber-matrix interface.

Based on the above researches, researchers have been investigated tensile and flexural properties of the nano-particle modified composite laminates. To the best of found knowledge, researchers in literature did not inspect the effect
of nano-silica content on tensile and flexural properties of intralaminar carbon/Kevlar fiber reinforced epoxy (CKRE) composite. In this work, the tensile and flexural of CKRE composite were calculated with the use of nano-silica particles. In addition, the nano-silica variation of 0.5, 1.0, 1.5, 2.5 and 3 wt% contents were incorporated with CKRE composites.

II. MATERIALS AND METHODS

Epoxy risen (Momentive-MGS L285) mixed with the hardener (Momentive-MGS H285) by a stoichiometric ratio of 100:40. Carbon/Kevlar twill 2/2 woven with areal density of 190 g/m² and thickness 0.23 mm are used as reinforcement in the lamina and it has high impact resistance and tensile strength. All above materials were supplied by DOST Chemical Industrial Raw Materials Industry, Turkey. Nanosilica was obtained from Grafen Chemical Industries, Turkey with a high purity 99.5%, average particle size of (15 nm), specific surface area (300 m²/g), and bulk density (0.05 g/cm³). Eight Layers of carbon/Kevlar were prepared to show hybridization effects. The composites prepared for this study by adding silica nanoparticles filler in epoxy resin with five different weight percentage fractions as 0.5, 1.0, 1.5, 2.5 and 3.0 wt%. Epoxy resin was mixed with nano-silica particles for 20 minutes after that the hardener was added and mixed to obtain homogeneity, afterword the mixture was poured upon the layers layer after layer to the last one (8 layers) (Fig. 1), then laminated fabrics was laid on the flat mold (Fig. 2) and subjected to 120 kPa pressure for 1 h curing time with 80°C temperature (Fig. 3). Then, the composite laminates were cooled to room temperature under pressure for three hours at least. Finally the composite laminate removed from the mold to get a fine finished composite plate.

The produced composite laminate in size of 220 mm × 200 mm was cut to the required size specimens according to the standards ASTM D 638 [13] for tensile test and ASTM D 790 [14] for flexural test, by using CNC machine. The produced tensile and flexural test specimens were given in Fig. 4.

Fig. 4 (a) Tensile specimens, (b) flexural specimens.

III. MECHANICAL TESTS

The tensile and flexural properties of the composite specimens were determined at room temperature using the Shimadzu testing machine AG-X series (Kyoto, Japan) (Fig. 5a and b). Suitable specimens were prepared with size of 165 mm × 13 mm for a gauge length of 50 mm for tensile test and 200 mm × 12.7 with span to thickness ratio of 32:1 for flexural test. The thickness of tensile and flexural specimens was in range of 2.5±0.1 mm due to variation of nano-silica content. The crosshead speed was 2 mm/min for tensile test and 3 mm/min for flexural test. At least four specimens were tested for each composite and the average value was depended.

The flexural properties were determined from the test machine data’s by using the following equations.

\[
\sigma_F = \frac{3P_{max}L}{2bh^2}
\left[1 + 6\left(\frac{D}{L}\right)^2 - 4\left(\frac{h}{L}\right)\left(\frac{D}{L}\right)\right]
\]  
\[
\varepsilon_F = \frac{6Dh}{L^2}
\]  

Where L, b and h are the span, width and depth of the specimen, respectively, D is the maximum deflection before failure and P is the load at a given point on the load-deflection curve.
Therefore, the highest improvement of flexural strength was obtained at 1.5 wt% content of nano-silica with maximum increment of 54.2%. The flexural tests showed a linear response of the stress-strain curves (Fig. 7) of the studied composites, then the fracture was occurred and the flexural strength decreased gradually. This figure also indicates that the failure strain is significantly increased with addition of nano-silica particles. As shown in Fig. 8, the specimens failed at the specimen center by bending load that failure was started with matrix cracking then fibers breakage and carbon/Kevlar layers delamination between compression and tension sides.

**IV. RESULTS AND DISCUSSION**

Table I displays the tensile and flexural properties of CKRE and CKRE-NS composites for various nano-silica contents. As shown in Fig. 6 and corresponding data in Table I, the addition of nano-silica always improved composite tensile strength at the studied percentages. The maximum improvement in tensile strength is 46.8% at particle content 3 wt%. Moreover, the elongation at break also increased with the addition of nano-silica particles. Hence, the elongation at break increased by 32.5% with addition of nano-silica having 3 wt%. All the specimens were broken without any nicking and the fracture surfaces were flat (Fig. 8), that means the specimens fail in a brittle fashion during tensile test. Besides, there was no effective reducing in the cross sectional area of the specimens. In addition, whether it was filled or unfilled with nano-silica particles, the tensile samples were failed at higher stress. This suggests that the nano-filler-matrix interaction is very strong therefore the nanocomposites exhibited higher strength compared to the pristine intralaminar hybrid composites.

As shown in Table I and Fig. 7, flexural strength has been improved by addition of nano-silica particles to the CKRE. Hence, the composite flexural strength was increased from 428 MPa for unfilled CKRE to reach 659 MPa with nano-silica content of 1.5 wt%, afterword flexural strength follows the trend of decreasing to reach 474 MPa at content of 3 wt%.

**Table I**

<table>
<thead>
<tr>
<th>Composite type</th>
<th>NS content (wt%)</th>
<th>Tensile strength (MPa)</th>
<th>Elongation at break (%)</th>
<th>Flexural strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CKRE</td>
<td>0</td>
<td>372 (±0.07)</td>
<td>2.77 (±0.09)</td>
<td>428 (±10)</td>
</tr>
<tr>
<td>CKRE-NS0.5</td>
<td>0.5</td>
<td>406 (±0.04)</td>
<td>3.12 (±0.18)</td>
<td>548 (±15)</td>
</tr>
<tr>
<td>CKRE-NS1</td>
<td>1</td>
<td>429 (±10)</td>
<td>2.98 (±0.10)</td>
<td>581 (±17)</td>
</tr>
<tr>
<td>CKRE-NS1.5</td>
<td>1.5</td>
<td>448 (±0.06)</td>
<td>3.45 (±0.15)</td>
<td>659 (±12)</td>
</tr>
<tr>
<td>CKRE-NS2.5</td>
<td>2.5</td>
<td>491 (±12)</td>
<td>3.27 (±0.12)</td>
<td>526 (±09)</td>
</tr>
<tr>
<td>CKRE-NS3</td>
<td>3</td>
<td>546 (±0.09)</td>
<td>3.67 (±0.17)</td>
<td>474 (±19)</td>
</tr>
</tbody>
</table>

**Fig. 6 Tensile stress-strain curves of the composites.**

This improvement of tensile and flexural properties attributed to the chemical compatibility of the nano-silica particles with epoxy resin and S-glass fibers in the composite laminate system. Furthermore, the flexural properties were degraded when nano-silica content exceeded 1.5 wt% and that may be ascribed to the particle aggregation phenomena which forming weaknesses in composite laminate and decreasing flexural strength.
V. CONCLUSIONS

The effects of nano-silica particles with variation in content on tensile and flexural properties of the carbon/Kevlar fabric/epoxy composites were inspected. The highest improvement of the tensile and flexural strength for CKRE-NS composites was obtained at nano-silica content of 3 and 1.5 wt%, with maximum increment of 46.8% and 54.2%, respectively. Generally, the tensile and flexural failure strains of the CKRE-NS composites were increased. Indeed the above mechanical properties were improved with nano-silica addition. Hence, this performance indicates the good adhesion strength and chemical compatibility of the nano-silica particles with carbon/Kevlar fabric/epoxy composite system.

REFERENCES


The Influence of Micro-Scale Perlite Inclusion within the Adhesive Epoxy Resin on Tensile Behavior of Glass-Epoxy Laminates Adhesively Bonded Single-strap Repairs

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Abstract—In this study, the tensile performance of epoxy adhesive with inclusion of micro-scale perlite particles was investigated for glass-epoxy laminates adhesively bonded single-strap repairs. Micro-scale perlite particles were used as additive material with different mass contents (plain, 5, 10, 15% wt) within the epoxy resin. Composite laminates were weakened by opening circular cutout at the center of them, then repaired by a circular and same composite laminates. The repairmen of the weakened laminates was explored two different patch ratios between patch and cutout diameter, incorporating adhesive epoxy with different perlite particle inclusions. Results showed that tensile strength of repaired samples reached its maximum value when perlite filler content is at 10 %.

Keywords—Composite, Patch repair, Adhesive, Perlite, Fiber

I. INTRODUCTION

The usage of the adhesives has been increasing as a process of the material repair to enhance the service life of damaged parts [1-3]. The adhesively bonded patch repairs reduce stresses around the crack of damaged region by performing load transfer through patch into panel and thereby prevent the crack tip from opening and growing [4]. As the usage of the high performance of adhesives and repairs, the repair of the load carrying components and structures may significantly contribute the improvement of the stress and stiffness. Two types of the patch repairs are available according to geometric shape of the samples: (1) Double (symmetric) sided and (2) single (asymmetric) sided configurations. These types of repairs were used in engineering applications depending on practical applications and space availability [4-5].

The adhesive properties are an important parameter for performances of the bonded composite repair. Bachir et al. [6] investigated the performance of the adhesives at the crack tips, showing that high shear modulus of the adhesives yields the stress intensity factor. They showed that adhesive properties can be optimized to increase performance of the repair by the reduction of the adhesive failure.

Filler is the most commonly used in the reinforcement of polymer matrix composite materials. Many studies related with the effect of particulate filler on mechanical properties of polymer composites can be found from literature [7-9], indicating that stiffness can be improved by the inclusion of the micro or nano scale particles. Sumita et al. [10] indicated the effect of particle size by replacing micro scale silica with its nano scale counterpart. They found that incorporation of nanoparticles resulted the higher mechanical properties for polymer composites. Several researchers [11-14] have shown the improvement of the strength of adhesive joints such as adding powders, particles, random and woven fibers to the adhesive layer.

It is evident from literature survey that mechanical properties of polymer matrix composites were significantly affected by particle content, particle size and particle/matrix adhesion. Present study aims to investigate the mechanical performance of S-glass fiber reinforced composite laminates having adhesively patched composite laminates with a central hole. Epoxy as an adherent was modified by incorporating microscale perlite filler for different epoxy/perlrite filler mixing ratios. The load bearing capacity of samples was explored in terms of force-deflection relation and results were compared with each other for different patch ratios. In addition, damaged surfaces were identified after the tensile tests.

II. MATERIALS AND PROCEDURES

A. Production of test samples

The material used for both composite laminates and patch is S-glass/epoxy prepreg supplied by Küçükparmak Company in Turkey. An epoxy resin (MOMENTIVE-MGS L285) with hardener (MOMENTIVE-MGS H285) at a stoichiometric ratio
of 100:40 was used as the matrix. The major mechanical properties of both epoxy and S-glass fiber are listed in Table 1.

<table>
<thead>
<tr>
<th>Plates and patches</th>
<th>MGS Hexion epoxy resin</th>
<th>Elastic Property</th>
<th>Tensile Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>E₁₂=19.6 GPa v₁₂=0.14 G₁₂=3.8GPa</td>
<td>3.0–3.3</td>
<td>70–80 GPa</td>
<td>MPa</td>
</tr>
<tr>
<td>E₂₁=19.6 GPa v₂₁=0.08 G₂₁=3.8GPa</td>
<td>Density</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E₂₃=11.7 GPa v₂₃=0.08 G₂₃=3.8GPa</td>
<td>1.18 g/m³</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hand lay-up technique using a hot press was used for fabrication of composite samples with curing procedure as shown in Fig. 1. Both composite plates and patches are designed in stacking sequence of [0/90]S during the production process.

Cured laminates were cut in the size of 100x50 mm size of the shape using a controlled CNC cutting machine. For notched samples, a central hole of the 10 mm size was drilled, which yields the patch repair ratio (patch diameter (D) to hole diameter (d)) as 2 and 3. Patch diameters used for patch ratios were 20 and 30 mm, respectively. During the process, a sandpaper was used to be polished samples, surfaces of the samples are first polished with fine grade sandpaper and followed by cleaning with acetone before bonding.

In the present study, epoxy based adhesive was used for joining of patches. While gluing the patches with adhesive, micro-scale perlite fillers were mixed with adhesive epoxy by different mass ratios as 0, 5, 10 and 15 % wt, respectively. Perlite filler has been used as additive material within the epoxy resin and mixing ratios were provided in Table 2.

### B. Tensile tests

Tensile tests were performed a controlled tensile test machine of Shimadzu AG-X with a load carrying capacity of 300 kN at cross head speed of 1 mm/ min as shown in Fig. 2 (a). Test samples were prepared as shown in Fig. 2 (b) and schematically illustrated in Fig. 2 (c). Three samples were tested for each groups and their average results were taken as a final result. Load bearing capacity and degree of patch repair improvement of the samples were identified and compared. The failure and fractured surfaces of the samples were also observed and reported by comparing for different patch repair ratios.

### III. RESULTS AND DISCUSSIONS

Patch repair performances of the samples were examined with two different patch repair ratios (2 ad 3). Tensile properties were measured for different mass ratios of perlite particle by mixing adhesive epoxy. The results of the tensile tests were listed in Table 3. Force-deflection relations and their maximum values were illustrated in Fig. 3. As can be seen from the results, incorporation of microscale perlite particles was resulted a significant increase in tensile strength, while further
increase in perlite content in the epoxy resin caused a reverse effect, showing the decrease of tensile strength values. All curves showed the similar trend. Maximum tensile force has been increased up to 10% wt content of perlite, then the value was decreased rapidly. This is attributed the distribution and weight percentages of particles in the adhesive epoxy, resulting the higher strength between particle-matrix interphases. According to test results, maximum patch repair performance in tensile strength (10% wt content of perlite particles) was recorded as 16.5 % for D/d=2 and 20.9 % for D/d=3 compared with the pure epoxy adhesive. This is also attributed the distribution and weight percentages of particles in the epoxy, resulting the higher strength between particle-matrix interphases. However, opening a central hole resulted the reduction of tensile strength about 60 %. When notched samples are patched with different patch ratio and epoxy adhesive properties, the samples of 2T-10 and 3T-10 have shown the highest improvement in tensile properties compared with others.

### Table 3

<table>
<thead>
<tr>
<th>Material</th>
<th>$F_{max}$ (kN)</th>
<th>$X_{max}$ (mm)</th>
<th>Material</th>
<th>$F_{max}$ (kN)</th>
<th>$X_{max}$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With hole</td>
<td>13.84</td>
<td>3.47</td>
<td>With hole</td>
<td>13.84</td>
<td>3.47</td>
</tr>
<tr>
<td>Without hole</td>
<td>33.88</td>
<td>5.97</td>
<td>Without hole</td>
<td>33.88</td>
<td>5.97</td>
</tr>
<tr>
<td>2T-0, control</td>
<td>15.01</td>
<td>3.07</td>
<td>3T-0, control</td>
<td>15.43</td>
<td>2.93</td>
</tr>
<tr>
<td>2T-10</td>
<td>18.46</td>
<td>3.74</td>
<td>3T-10</td>
<td>19.01</td>
<td>3.78</td>
</tr>
<tr>
<td>2T-15</td>
<td>15.69</td>
<td>3.18</td>
<td>3T-15</td>
<td>16.67</td>
<td>3.43</td>
</tr>
</tbody>
</table>

Some fractured samples after tensile tests were illustrated in Fig. 4. It can be observed that the damaged surfaces of the repaired composites are mainly affected by the material behaviour of the adhesive epoxy in terms of particle filler content. The increase of perlite content in the adhesive resulted the increase in brittle behaviour of the adhesive which led to decrease in load bearing capacity of the samples.

Fig. 3. Patch repair performance of the samples

Fig. 4. Some fractured test samples after the tensile tests

### IV. CONCLUSIONS

The influence of perlite particle inclusion patch repairmen of S-glass reinforced composite laminates were investigated by mixing within the adhesive epoxy resin with different contents (5, 10, 15 and 20 % by mass of particle loading) of perlite filler. As a result of this study, following conclusions can be drawn:

- A lower content of particulate inclusion significantly increases tensile strength and further increase in Perlite content causes the reverse effect, resulting the decrease of load carrying capacity,

- In the case of Perlite filler content is at 10%, tensile strength reaches its maximum value due to the improved particle matrix interphase strength,

- Patch repair performance of the samples with D/d=3 is greater than samples with D/d=2,

- Maximum patch repair performance in tensile strength (10% wt content of perlite particles) was recorded as 16.5 % for D/d=2 and 20.9 % for D/d=3 compared with the pure epoxy adhesive,
• It can be observed that the damaged surfaces of the repaired composites are mainly effected by the material behaviour of the adhesive epoxy in terms of particle filler content,

• Consequently, joining performance of composite laminates can be improved by mixing of Perlite filler with an adhesive epoxy at low weight percentage of Perlite filler, contributing the resolve an important engineering problem during the service.

REFERENCES

Effect of Olive Pomace on the Mechanical Property of glass fiber reinforced epoxy composites.

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Abstract—This work aims to study the effect of the mixing of natural particles of micro-size olive pomace (OP) on the tensile and flexural properties of glass fibre reinforced polymer composite (GFRP). Hence, the mechanical behaviour of recycled olive pomace filled glass fibre reinforced epoxy composites was studied in order to develop an engineering material for industrial applications. The modifying of GFRP was conducting by adding six weight fractions of olive pomace (0.5, 1, 2, 5, 10, and 15%) with a grain size of (75 μm). The composite specimens were prepared by hand lay-up technique and cut according to ASTM standards. It's found that the highest values of flexural and tensile strength happened at 5 wt % of OP filler. Also, the tensile results showed that with more addition of OP above 5% the elongation at break decreased. The flexural modulus was improved with addition of OP particles in GFRP composite.

Keywords— Glass fibre, olive pomace, polymer composite, Hybrid composite.

I. INTRODUCTION

Olives are among the most extensively cultivated fruit crops in the world. The total world production of olives and virgin olive oil was reported to be 20.8 and 3.27 million tons, respectively, for the year 2010 [1]. Olive cultivation is particularly widespread throughout the Mediterranean region and plays an important role in its economy, local heritage and environment protection. The largest olive-producing countries are located in the Mediterranean and Middle Eastern regions providing 98% of the total cultivated surface area, and 99% of the total olive fruit production [2].

Turkey is ranked among the leading olive-oil producers, with over 180 million olive trees grown on 0.7 million hectares cultivation area and an average annual production amounting to 500 thousand metric tons table olive production annually and olive oil production annually. However, a major problem which significantly affects the environmental sustainability of this agricultural activity is the disposal of residues generated from the industrial extraction of olive oil [3].

In recent years, many studies were dealt with utilizing cellulose fillers like palm kernel shell, olive pomace, pineapple leaf, wood, coconut shell as fillers within organic polymers. Therefore, the synthetic fillers were replaced through utilization of natural fillers as reinforcement in thermoplastic and thermoset polymer composites in an attempt to minimize the cost, increase productivity and enhance the mechanical properties of the product [4]. Fillers and fibers like olive pomace, oil palm empty fruit bunch, kola nitride wood fiber, as well as several fillers such as rice husk were used as reinforcing agents for different thermoplastic and thermosetting plastic resins [5, 6]. There is an overwhelming interest in filler and natural fiber reinforced polymers owing to their ease of processing and low cost as some of these fillers are regarded as waste. In the development of epoxy/eggshell particulate composites, the density and hardness values of the epoxy/eggshell particulate composites increased steadily with the increasing eggshell addition, compressive strength, flexural strength and impact energy increased [7]. The effect of untreated and treated coconut shell reinforced unsaturated polyester composites were studied and it was observed that the mechanical and thermal properties of unsaturated polyester/coconut shell composites were enhanced [8].

Qutaiba [9] Studied on sustainable reinforced polymer composite by using olive pits powder as a filler material for epoxy resin. The influence of the untreated and treated olive pits powder on the mechanical properties of the composites was examined. The results show significant improvements in mechanical properties for composites reinforced with treated olive pits than composites reinforced with untreated olive pits. Koutsomitopoulou et al. [10] illustrated the effect of olive pits powder reinforced polylactic-matrix. This study was focused on recycling potential of some waste materials, such as olive pits, i.e. the solid phase derived from an olive oil mill, blended with thermoplastic polymers and used for the production of new materials applied in manufacturing containers and formworks. An increase in the tensile modulus but a decrease of the flexural strength may be due to the poor interfacial bonding between olive pit powder and polylactic. Gharbi et al. [11] investigate the effect of the incorporation of the olive nuts flour up to 60% loading in unsaturated polyester on the flexural properties, impact strength, thermo-mechanical properties and water absorption behavior. The olive nuts flour was prepared from the exhausted solid olive oil mills after mechanical grinding treatment. A steady enhancement in the flexural modulus was noted by the olive nuts flour.
incorporation. Therefore, the applying of glass fiber in a natural particulate-filled polymer to produce cheapest composite laminates having varied applications and good properties like high stiffness, strength, thermal stability and resistance to chemical hurt [12,13].

The aim of this study is to investigate the tensile and flexural properties of S-glass fiber reinforced epoxy (GFRE) composite filled by olive pomace particles with particle content of (0.5, 1, 2, 5, 10, and 15%). The composite specimens were prepared using hand-layup technique, in addition they cut and tested according to ASTM standards.

II. MATERIALS AND METHODS

In order to manufacture composite specimens, woven Glass fiber with an areal density of 200 g/cm² was used as a reinforcement material in the composite laminate (Fig. 1a). Epoxy resin (Momentive-MGS L285) with hardener (Momentive-MGS H285) in a stoichiometric ratio of 100:40 was used in the common matrix. The modifying of GFRP composite was conducting by using six weight fractions of olive pomace (Fig. 1b) as 0.5, 1, 2, 5, 10, and 15% with a grain size of (75 μm). Composite laminates were prepared using hand lay-up method by mixing olive pomace with epoxy resin (Fig. 2) for 20 minutes then hardener was added, the mixture was applied to the glass fibers layers until all the 8 layers. Then, modified laminate with dimensions of 250 mm ×200 mm were subjected to 0.1 Mpa pressure in the flat mold for 1 h curing time with 80°C temperature. Composite laminates were cooled to room temperature under the pressure (Fig. 3).

III. MECHANICAL TESTS

After the production process, the test specimens were cut from the composite sheet to the required size as per ASTM standards (D638–10) [14] for tensile test and (D-790) [15] for the flexural test, by using CNC machine. The produced tensile and flexural test specimens are given in Fig. 4, and their dimensions are illustrated in Fig. 5. The thickness of the composite laminates was measured in range of 1.85±0.25 mm. Mechanical properties of the composite laminates were obtained using the Shimadzu AG-X series testing machine (Shimadzu Corporation, Kyoto, Japan) (Fig. 6). Suitable specimens were prepared with size of 165 × 13 mm for a gauge length of 50 mm for tensile test and 200 × 12.7 with span to thickness ratio of 32:1 for flexural test. The tensile and flexural properties of the composite specimens were determined using crosshead speed of 2 mm/min for tensile test and 3 mm/min for flexural test. At least three specimens for tensile and four for flexural were tested for each composite, and the average value was calculated.
IV. RESULTS AND DISCUSSION

Table I displays the tensile properties of GFRP and GFRP-OP composites for various olive pomace contents. As shown in Fig. 7 and corresponding data in Table I, the tensile strength of unfilled GFRP composite is 339.75 MPa. After this content the tensile strength was degraded. Moreover, the elongation at break (followed same behavior of strength) also was decreased then increased with the addition of olive pomace particles then decreased. Therefore, the elongation at break reached maximum with increment of 22.6% at OP content of 5 wt%. All the specimens were broken without any nicking and the fracture surfaces were flat (Fig. 8), that means the specimens fail in a brittle fashion during tensile test. Besides, there was no effective reducing in the cross sectional area of the specimens. Therefore, the samples of GFRP-OP composites show a brittle style. In addition, whether it was filled or unfilled with olive pomace particles, the tensile samples were failed at higher stress.

Fig. 8 Tensile specimens after testing.

As shown in Table II and Figs. 9 and 10, flexural strength has been improved by addition of olive pomace particles to the glass fabric/epoxy composite. Hence, the composite flexural strength was increased from 465.56 MPa for unfilled GFRP to reach 630.90 MPa with olive pomace content of 5 wt%, afterword flexural strength follow the trend of decreasing to reach 291.81 MPa at content of 15 wt%. Therefore, the highest improvement of flexural strength was obtained at 5 wt% content of olive pomace with maximum increment of 35.5 %. The flexural tests showed a linear response of the stress-strain curves (Fig. 9) of the studied composites, then the fracture was occurred and the flexural strength decreased suddenly. This figure also Table II indicates that the failure strain is decreased with addition of olive pomace particles.

Furthermore, the flexural modulus enhanced with addition organic particle of OP, which modulus was increased from 17.84 GPa for unfilled GFRP to 24.24 GPa at OP particles of 5 wt%, then decreased to 18.41 GPa at OP particles of 15 wt% (Fig. 10). The maximum increment of flexural modulus was 35.9%

As shown in Fig. 11, the specimens failed at the specimen center by bending load, that failure was started with matrix cracking then fibers breakage and Glass/epoxy layers delamination between compression and tension sides.

Fig. 7 Tensile stress-strain curves of the glass fiber reinforced epoxy composite filled with olive pomace.

![Graph](image.png)

To sum up, this improvement of tensile and flexural properties attributed to the chemical compatibility of the olive pomace particles with epoxy resin and S-glass fibers in the
composite laminate system. Furthermore, the tensile and flexural properties were degraded when nano-silica content exceeded 5 wt% and that may be ascribed to the particle aggregation phenomena which forming weaknesses in composite laminate and decreasing flexural strength.

The highest improvement of the tensile and flexural strength for GRFP-OP composites was obtained at olive pomace content of 5 wt%, with maximum increment of 15.9% and 35.5%, respectively. Generally, the flexural modulus was enhanced. Indeed the above mechanical properties were improved with olive pomace addition. Hence, this performance indicates the good adhesion strength and chemical compatibility of the olive pomace particles with glass fabric/epoxy composite system.

REFERENCES


V. CONCLUSIONS

The tensile and flexural properties were affected according to tensile and flexural tests results of glass fiber reinforced epoxy composite filled with olive pomace particles with variation in content. The highest improvement of the tensile and flexural strength for GRFP-OP composites was obtained at olive pomace content of 5 wt%, with maximum increment of 15.9% and 35.5%, respectively. Generally, the flexural modulus was enhanced. Indeed the above mechanical properties were improved with olive pomace addition. Hence, this performance indicates the good adhesion strength and chemical compatibility of the olive pomace particles with glass fabric/epoxy composite system.
Effect Of Density And Blend Rates Of Composite Panels Reinforced With Polyester Fibres To Tensile Resistance

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Abstract— Using of composite materials are getting important for many areas like aviation and defence industry, land and marine transportation, energy, infrastructure and construction sectors due to increasing necessity for alternative materials nowadays. Therefore; in competitive markets having increased consumption and production of materials, manufacturers are in tendency to add difference and functionality on their products. One of important ways of creating difference and functionality is to choose most available production methods and processes simultaneously with materials and carry out all of these in low costs.

In this research, composite materials reinforced with polyester fibres which are known with low cost and high strength features, were obtained by using a resin as bonder. Phenol formaldehyde was preferred as bonder resin by the reason of having low thermal conductivity, high bonding, good water resistance and low cost characteristics during the production of composite materials. Blend consisted of opened polyester fibres together with bonder, was pressed in patterns at 130 °C. Composite materials were produced in two different densities and four blend rate. Tensile tests were applied to all composite samples to observe the performance in areas which they can be used. Obtained test results were evaluated by making essential interpretations.

Keywords— Composites, Polyester, Fibres, Phenol formaldehyde, Tensile test.

I. INTRODUCTION

Materials are generally divided three main groups as metals, ceramics and organic materials. These three groups have more&less advantages and disadvantages according to each other [1]. Beside these three groups, materials are non uniform solid consisting of two or more different materials that are mechanically or chemically bonded together, are called composite materials [6-7]. Each of the various components retains its identity in the composite and maintains its characteristic structure and properties [6]. Composite materials are combined with macro structural materials in order to create new features according to area where materials will be used. It can be also thought for composite materials as "ordered material". Materials combined in atomic or molecular dimensions are not classified as composite materials due to being homogenous in macroscopic dimensions. Advantage of composite material is gathering best features of ingredients. Nowadays, materials which are developed and still developing progressively, have been using for thousands of years, indeed [1]. It is seen the structure of a composite material in Fig. 1.

Today composite materials are used in many important and vital engineering applications due to having advantages and varieties. In some applications, polymers do not provide desired physical and chemical features by self. In these cases, these polymers are supported by various textile fibres in different ratios according to desired features. Nowadays, these kinds of production methods are very common to provide "ordered material". Suitability of engineering materials in terms of durability, flexibility, lightness, resistance to environment conditions (humidity, sun lights etc.) as main features and fatigue against period of time, impact, tensile, bending, compression and chemical resistance as assistive features, are investigated according to areas where materials will perform. It is quite rare to find a material having all these features only in itself. Composites which are launched to be manufactured since 1950's as an alternative material, started to solve suppling problem of materials including all different
kinds of features together. Interest and attention to polymeric composites reinforced with fibres, are increasing progressively by reason of high strength and module values [3].

The matrix forms a significant volume fraction of a polymer composite and it has a number of critical functions; it binds the reinforcements together, maintains the shape of a component and transfers the applied load to the reinforcing fibres. It protects the reinforcing fibres from degradation, due to abrasion or environmental attack. It contributes significantly to the mechanical properties of structural polymer composites, acting to resist delamination between plies of reinforcements and to inhibit fibre buckling during compression. Thermoplastics are used in certain applications but constitute a relatively small sector of the structural composites market. Matrices used for structural composites are mainly thermosetting plastics, such as polyester resins, epoxy resins, phenolic resins and vinyl-ester resins. Thermosetting plastic systems generally consist of liquid mixtures of relatively low molar mass reactants, such as monomers and/or prepolymers, which polymerise upon heating to form highly-cross linked, network polymers [8-16].


In the research on literature of composites consisted of natural fibres as a reinforcing component, it is observed that most of investigations were carried out to improve bonding of natural fibres to interface or searching mechanical features. Investigations in which natural fibres and synthetic fibres (linen/glass fibre, hemp/glass fibre, basalt/glass fibre, jute/glass fibre, felt/glass fibre) used together, are observed, as well [5]. Cross-sectional view of a composite blade consisted of different kinds of fibres and fabrics, is shown in Fig.2.

**II. MATERIAL AND METHOD**

The aim of this study is to create a difference than the other studies and produce low cost and high strength composites through a process which is not complex. Thus, polyester fibres which are used also in textile sector were chosen as a reinforcing material in our products. The most important reasons of choosing polyester fibre are cheapness and high strength values. Polyester fibre prices in market start from 3,5 TL/kg. Physical properties of some chemical fibres are indicated in table I.

**TABLE I**

<table>
<thead>
<tr>
<th>Fibre Type</th>
<th>Density (g/cm³)</th>
<th>Melting Temperature (°C)</th>
<th>Humidity (%)</th>
<th>Tensile (mN/tex)</th>
<th>Strength (Mpa)</th>
<th>Module (N/tex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyamide</td>
<td>1.14</td>
<td>258</td>
<td>5</td>
<td>840</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Polyester</td>
<td>1.38</td>
<td>258</td>
<td>&lt;1</td>
<td>820</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Polyethylene</td>
<td>0.95</td>
<td>140</td>
<td>0</td>
<td>550</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Polypropylene</td>
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<td>165</td>
<td>0</td>
<td>620</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Aramid</td>
<td>1.45</td>
<td>500</td>
<td>1-7</td>
<td>2000</td>
<td>3,5</td>
<td>60</td>
</tr>
<tr>
<td>High Perf. PE</td>
<td>0.97</td>
<td>150</td>
<td>0</td>
<td>3500</td>
<td>3,5</td>
<td>100</td>
</tr>
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</table>

Phenol-formaldehyde as shown in Fig. 4, is preferred as a bonder to generate composite materials due to having low thermal conductivity, strong bonding and high resistance against water and being cheap features. Phenol-formaldehyde prices in market are about 750 TL/ton.
Before producing of composite samples, polyester fibres being in floc cases as can be seen in Fig. 3, opened by hand. Then, phenol-formaldehyde is mixed in one-to-one ratio with water and sprayed on opened polyester fibres to provide bonding. It is required heat for phenol-formaldehyde to be activated and establish chemical bond with polyester fibres. Thus, in first step composite samples were produced by pressing the blend consisted of polyester fibres and sprayed bonder and then laid with hand in a pattern heated at 130 °C. Pattern is shown in Fig. 5. Polyester film was used for not adhering by the reason of heat effect to patterns.

Tensile tests are applied to samples produced in 2 different density and 4 different fibre/bonder rate to observe the performance of composite materials where they can be used. Tensile tests were carried out for samples in size of 50x50x0,35 cm according to ASTM D 638 standards. One of produced samples can be seen in Fig. 6 and codes of samples are shown in table II. Shimadzu AG-IS device with 1 mm/min tensioning speed, was used for tensile tests in standard atmosphere conditions. 5 measurements were carried out for each sample and average of results was evaluated.

III. RESULTS AND DISCUSSION

Tensile test results of samples were analysed in this session and comparisons and interpretations of results were also mentioned. First, test results were evaluated in terms of investigating the effect of changing density of samples having same fibre/bonder rate and then, it is remained in term of investigating the effect of fibre/bonder rate of samples having same density.
When test results of samples were analysed, it is seen that tensile strength values for samples produced in both density are decreasing together with increasing of fibre rates in Fig. 7. It is observed that together with increasing fibre rate in samples, gap between tensile strength values of samples having same fibre/bonder rate but in same density, is decreasing. This case indicates us that main structural material makes samples strength is phenol-formaldehyde used as bonder. This impression is more distinct and clear in samples having more density in Fig. 9. Highest tensile test value belongs to B1 sample and lowest tensile test value belongs to A4. When young modulus of samples is evaluated in Fig. 6, it is understood that all samples having higher density in same fibre/bonder rate performs higher young modulus values. Highest young modulus belongs to B1, lowest one belongs to A4. This shows that rigidity of materials is decreasing together with increasing of fibre rate.

As it is seen clear in fig. 8, if samples have same density, tensile strength is decreasing together with increasing of fibre rate. This decrease (slope) is moving slowly until a specific point and then getting rapid. It is thought that possibility of occurring non-parallel, tangled and nested fibre structure in sample will increase by the reason hand laying of fibres in pattern together with increasing fibre rate. So these tangled fibres structure causes lower tensile strengths to sample instead of causing higher tensile strength values. In other words, these tangled fibres take space in samples and do not contribute to tensile strength values. Together with decreasing of bonder rate and increasing of fibre rate causes rapid decrease in tensile strength values after a specific point. It is thought that decreasing in tensile strength values of B1, B2, B3, B4 is faster than A1, A2, A3, A4 is a proof this explanation.

IV. CONCLUSION

One of most important aim of this study is to produce samples at low cost as much as possible. So maximum price of one samples produced in size of 50x50x0,35 cm is 0,45 TL and minimum one is 0,16 TL. On the other side, tensile tests were applied to samples. Thus, tensile strength and young modulus values obtained from tensile test informed about performance of sample according to using areas. It is observed that together with density increase of all samples having same fibre/bonder rate, tensile strength values are also increasing. Highest strength value (83,44 MPa) belongs to B1, lowest one (50,12) belongs to A1. It is seen from figures that together with increasing fibre rate in samples having same density, tensile strength values are decreasing. Rate of decrease is getting faster with increasing of fibre rate in samples. It can be thought that tangled fibres structure in samples causes lower tensile strength instead of higher tensile strength values. From this point of view, in order to increase contribution of fibres to tensile strength, it is supposed pressed in patterns after spraying bonder to all fibres parallelised to each other in one direction. So vertically arranged fibres against force will increase the strength.
V. ACKNOWLEDGEMENT

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ELECTROCHEMICAL STUDIES ON POLY(3,4-ETHYNYLIDIOXYTHIOPHENE)POLYMER AND ITS POTENTIAL APPLICATION IN ELECTROCHEMICAL CAPACITOR

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Abstract— Electrochemical studies on Poly(3,4-ethynylidioxythiophene) (PEDOT) electrode material as a conducting polymer and its potential application in electrochemical capacitor have been concentrated in this study. 3,4-ethynylidioxythiophene (EDOT) has been successfully electropolymerized in the presence of ionic liquid, 1-ethyl-3-methylimidazolium hydrogen sulphate (EMIMHSO4) and organic electrolyte medium, LiClO4/ACN electrolytes. Their capacitance performances were evaluated and compared with each other in the monomer free medium. The initial galvanostatic charge/discharge tests of PEDOT polymers were also investigated. The SEM studies show that the PEDOT films electropolymerized in EMIMHSO4 were highly porous and have a higher anion doping level than those electropolymerized in LiClO4/ACN electrolytes. Additionally, the symmetrical electrochemical capacitors based on two PEDOT electrodes were also constructed and characterized with electro-analytical methods. Furthermore results were compared with each other.

Keywords— electrochemical capacitor, PEDOT, ionic liquids, conducting polymers

I. INTRODUCTION

What would we do in case of power failure on emergency if we needed to electrical energy rapidly? Have you ever thought about it or how would we solve this problem? Certainly the most important subject that we can meet in this century is energy storage. As a solution to supply the all energy demands of in our modern world by considering ecological factors, new essential search are proceeding for low cost, and eco-friendly storage systems [1]. There are rapid developments of research in this field; such as rechargeable batteries, fuel cells and electrochemical capacitors, which could store energy with electrochemical methods, are the most important energy storage devices for these purposes.

The main difference between capacitors and electrochemical capacitors is about charge storage mechanism. Electrochemical capacitors store energy in the bulk with chemical reactants, whereas capacitor store energy directly with using dielectric sheet between conducting two plates [2].

Electrochemical capacitors also commonly known as “supercapacitors” or “ultracapacitor”, is a new class energy-storage devices whose specific performance characteristics fill the gap between capacitors and rechargeable batteries with the energy versus power density [3]. Batteries are low power devices compared to the capacitors but they have more energy densities. Supercapacitors can merge both these properties. Supercapacitors power density is also higher than the rechargeable batteries and its energy density is higher than conventional capacitors [4].

We can classify to supercapacitors into two types. These are electrochemical double layer capacitors (EDLCs) and pseudocapacitors. In EDLCs, the charge is stored electrostatically at the electrode-electrolyte interface in the form of double layers on either electrode which these double layers act as two serial capacitors on the electrical equivalent circuit, while in pseudocapacitors charge storage occurs via fast redox reactions [6]. Because of the pseudocapacitors charge storage mechanism is consisted of electroosorption, reduction-oxidation reactions, and intercalation processes, pseudocapacitors achieve more capacitances and energy densities than EDLCs [12]. The capacitance values of pseudocapacitors are 10-100 times higher than EDLC [13].

Structurally, a supercapacitor consist two electrodes which should be nonreactive porous plates and these electrodes are immersed in an electrolyte. Electrodes are separated by porous membrane [5]. The separator is soaked in electrolyte and prevents short circuits on device therefore; the separator should have a high electrical resistance and also need to be ion-permeable, to allow the ion transfer during charging/discharging [7]. The separator thickness is important in order to achieve the performance. The electrolyte potential range limits the working voltage of supercapacitor. This fact effect performance of supercapacitor due to capacitors charge storage capable is related to square of voltage (E=1/2CV2). Aqueous electrolytes typically have around 1 V adequate voltage, which is relativity lower than the organic electrolytes (around 3V), but the ionic conductivity of aqueous electrolytes is higher than organic electrolytes [8]. In generally, the
There are two types of intrinsically. Conductivity of conducting polymers delocalized π-E polymers have different band ga conjugated bond structure. Therefore it plays crucial role in determining the energy and power densities of supercapacitor. [9] If we want to design a high-performance super capacitor, the electroactive material on the electrode surface include high specific capacitance which this criteria may be gravimetric, volumetric or areal of active material, and large rate capability and also high cycle stability. At the same time active material should have low toxicity and low cost for economic and ecological in order to realize a high performance super capacitor [10].

Generally, electrode materials for EDLCs are carbon-based materials such as active carbon, carbon nanotubes and graphene. Likewise, redox active materials can be used for pseudocapacitor. These are transition metal oxides such as RuO$_2$, MnO$_2$, WO$_3$, NiO, Fe$_2$O$_3$ etc. and conducting polymers such as polypyrrole, polyaniline, polythiophene and its derivatives. All these materials have different properties, therefore its specific characters effect to the performance of super capacitor in different way [10]. For example, carbon-based materials provide high power density and high stability unlike have low specific capacitance, therefore, limits its application for high-energy density devices. Metal oxides have electroactive materials for pseudocapacitance and have wide charge-discharge potential range; however, their application is limited by surface area, low conductivity, high cost, toxicity, and poor stability [11]. The most capacitive performance of RuO$_2$ exhibits 720F/g values in metal oxides. But it has high cost and high toxicity in nature [6].

Another electroactive material for pseudocapacitors is conductive polymers (CP). CPs have the advantages with its unique properties such as, high specific capacitance, good conductivity, low cost, easy fabrication, good thermal and chemical stability and environmental friendless [11,14]. Conducting polymers store charge, not only in the polymer double layer, but also throughout the body of the polymer by rapid faradaic charge transfer by three-dimensional charge storage mechanism, therefore it has higher capacitances [12]. As an interesting property of CP, is also applicable for flexible application, due to their inherent flexible polymeric nature, which is a crucial requirement for the portable flexible electronics [11].

**A. Conducting Polymers**

Conducting polymers are electrically conducting polymers (ECPs) due to high mobility of electrons in conjugated bond structure. Because of the conducting polymers have different band gap between 1-3 eV conducting polymers may have metallic or semi-metallic properties [15]. Electrical energy conducted in conjugated polymers with delocalized π-electrons in its conjugated structure, intrinsically. Conductivity of conducting polymers enhance during delocalized π-electrons are accepted or released with chemical or electrochemical doping/un-doping processes [16]. There are two types of doping process below:

\[
\begin{align*}
\text{p-doping: } & \text{(CP) + nA} \leftrightarrow [(\text{CP})^+ n\text{A}^-] + ne^- \quad (1) \\
\text{n-doping: } & \text{(CP) + nC} \leftrightarrow [(\text{CP})^n n\text{C}^-] \quad (2)
\end{align*}
\]

Conducting polymers have intrinsic conductivity from a few S/cm to 500 S/cm in doped state [17].

Polymer based super capacitor devices have three configuration as per types of conducting polymers doping process. Type I or also known as symmetric, super capacitor using the same p-dopable polymer for both electrodes. Type II or also known as unsymmetric, super capacitor using two different p-dopable polymers have different potential ranges. Type III or also known as asymmetric, super capacitor using p-dopable polymer for positive electrode and also using n-dopable polymer for negative electrode [17,18].

Type III super capacitor device have theoretically highly capacitances because of the charge mechanism is observed the both electrodes, but n-doped polymers have high resistance and n doping process is difficult for conducting polymers [17].

For type I device, while one electrode fully p-doped in completely charged, another electrode becomes undoped state. When the device becomes completely discharged state, both electrodes become half p-doped state.

For type II device, while one electrode becomes fully p-doped in completely charged, another electrode becomes undoped state. When the device becomes completely discharged state, both electrodes become partially p-doped state. As the same way, for type III device, while both electrodes become undoped in discharged state, in completely charged state p-dopable polymer becomes p-doped, and n-dopable polymer becomes n-doped [19].

A lot of conducting polymers can be used for electrochemical capacitor. Specific capacitance in related to mass, of conducting polymers is an important selective way to choose all of these materials for electrochemical capacitors. PEDOT has a theoretical specific capacitance about 210 F/g, which is rather low in comparison to such (PANI) polyaniline (750 F/g), (PPY) polypyrrole (620 F/g) or (PT) polythiophene (485 F/g) [20].

PEDOT is one number of these conducting polymers of PT derivatives. It has a good thermal and chemical stability, fast electrochemical switching and a high electrical conductivity in the p-doped state (approximately 550 S/cm) [20]. Conducting polymers have low life cycles due to volumetric changes during the doping/de-doping processes. Volumetric changes occur during the insertion/de-insertion of counter ions and this changes result in swelling, shrinkage, cracks on polymer structure [21]. Therefore, PEDOT have attractive properties with regard to other ECPs for stability of device.

**B. Ionic Liquids**

Ionic liquids (ILs) are low-melting molten salts composed completely of anions and cations. In general, ionic liquids consists polyatomic organic cations and an inorganic or organic anions. It is also named as room temperature ionic
liquids (RTIL) because of its melt on near room temperature [22]. ILs have lots of advantages such as a wide liquid range, high ionic conductivity, a wide voltage window, non-volatility, and non-flammability [23,24]. ILs are salts in the liquid phase usually below 100 °C, and they dissolve both polar organic molecules. Mainly because of their low volatility, they are considered to be “eco-friendly solvents” [25]. Ionic liquids are resistant in a wide potential window (up to 4-6V) and provide a high cell voltage. [26]

The most commonly used ionic liquids consist imidazolium, pyridinium, pyrroldinium, phosphonium, piperidinium, pyrazolium, sulfonium, thiazolium, and ammonium cations and anions such as chloride, bromide, nitrate, acetate, hexafluorophosphate, tetrafluoroborate, alkylsulfate, alkylsulfonate and tosylate[27,28]. Among these systems, the physicochemical properties of 1-alkyl-3-methylimidazolium-based ionic liquids with various anions have been extensively investigated [29]. The alkyl imidazolium based ionic liquids have been investigated as possible electrolytes for their application as batteries and capacitors [30]. It is necessary to develop ILs with high conductivity and low viscosity. The viscosities of the ILs were increased with an alkyl spacer length. The potential reasons were increased Wan Der Walls interaction between the alkyl groups [32]. Environmentally friendly and electrochemically stable imidazolium cations with stable anions were used herein to synthesize ionic liquids [31]. Using an IL as device electrolyte allowed an extension of the voltage window of Type I ESCs by 60%, resulting in a 2.5-fold increase in the energy density obtained [32]. There are three main advantages of using ionic liquids for electrochemical capacitors. Firstly, the electrochemical activity of the polymer grown in ionic liquids is less affected by the nature of the cycling solvent than the polymer achieved in other solutions. Secondly, the porous structure of polymer offers a higher specific surface area that is convenient for dopant ions accessing into the polymer matrix and inducing higher charge to keep stable. And the last one, p type or n type polymer is more stable with using ionic liquids [33]. Recent studies have shown that ECPs can be electropolymerized using ILs as dopant and electrolyte and that polymers have shown improved cycling stability in ILs and gel electrolytes compared to organic electrolytes. This improved electrochemical performance and stability was mainly attributed to the lower volume changes observed for ECPs when using solvent-free electrolytes [34].

Although fluorinated ILs usually show better conductivity, non-fluorinated electrolytes are more attractive from a safety and environmental stand point. A non-fluorinated IL, 1-ethyl-3- methylimidazolium hydrogen sulfate (EMIMHSO₄), has been suggested as a proton conducting electrolyte for fuel cells [35]. In this work, EMIMHSO₄ was chosen as ionic liquid electrolyte.

In literature, a few study reported on type I electrochemical capacitors in related to combination with PEDOT polymer based electrode and ionic liquid electrolytes. Such as Pandey et al. have studied on PEDOT polymer with ionic liquid electrolyte to prepare electrochemical capacitor. They have characterized devices and have calculated the PEDOT electrodes specific capacitance of 154.5 F/g. Another study, Wei-Cheng Fu and al. have prepared PEDOT electrodes in combination with [BMI][BF₄] 1-butyl-3-methylimidazolium tetrafluoroborate and they have exhibited 191 F/g specific capacitance. As the same way Keke Liu and al. have studied electrochemical capacitors on PEDOT electrodes in [BMI][BF₄] ionic liquids and they have calculated the specific capacitance of device about 130 F/g.

II. Experimental Methods

3-4 Ethylenedioxythiophene (EDOT) and EMIMHSO₄ ionic liquid was purchased from Sigma Aldrich. In this work acetonitrile (ACN) and LiClO₄ were used as solvent and supporting electrolyte, respectively. EDOT monomer was polymerized with three electrode configurations using potentiostat in order to control electrode potential. Three main electroanalytical methods were used to investigate performance of electrochemical capacitor in this work. These are cyclic voltammetry, galvanostatic charge/discharge test and impedance spectroscopy analysis.

In this work we used Ag/AgCl electrode as a reference electrode and also Pt wire as counter electrode. Pt disc electrode was immersed into solution as working electrode. Its surface area was calculated as 0.02 cm². As a presence of monomer for electrochemical deposition, we prepared a solution which its concentration 0,1M EMIMHSO₄, 0,1M EDOT, 0,1M LiClO₄ in 3mL ACN solvent. Furthermore we prepared a monomer free solution with 0,1M LiClO₄ in 3 mL ACN solvent for all the electrochemical analysis. Electrodeposition method was realized in presence of ionic liquid and electroanalytical analysis was realized in monomer free medium.

III. Results and Discussion

The polymer film was grown potentiostatically at a DC potential of 1.7 V versus Ag/AgCl at 25°C. PEDOT was synthesized in an acetonitrile (ACN) based electrolyte containing 0.01 M EDOT monomer and 0.1 M LiClO₄. After deposition of PEDOT the substrates were washed in ACN solution. The FTIR spectroscopy analysis shows that the structure of the polymer film is consistent with that of the monomer. The peak one at 3120 cm⁻¹ is due to C–H stretching (–hydrogen) of external EDOT units disappear and other peaks still appear indicating that polymerization proceeds via C-2 and C-5 position of external EDOT units. The peak at about 1090 cm⁻¹ belongs to ClO₄⁻ dopant. The morphology of polymer film exhibits a densely packed structure morphology which comprises of uniform globular grains with size of about 80-150 nm. Thus, the electronic conductivity of the polymer may be improved due to more interconnected grains (densely packing) with uniformly distribution of globular grains.
Furthermore by incorporation of the ionic liquid, the P-150 CE exhibited more porous structure and larger active surface area in comparison to PEDOT without ionic liquid. Chronoamperometry method was used during electrodeposition of monomer on Pt disc electrode with constant potential. In this work we electrodeposited the EDOT monomer with a 1.7 V constant potential. Firstly, EDOT monomer was electrodeposited on Pt disc electrode the till 5 mC charge on electrode and scanned the polymer film using CV method with a 50 mVs⁻¹ scan rate in the potential range of 1.2 and -1.2 V. In Figure 1a, capacitive effect of polymer film on CV was adduced. Polymer film has a well defined and reversible doping process and a loop was seen on CV between -0.5 and 0.2 V potential ranges. This loop based on the pseudo-capacitive behaviour on electrode Figure 1(a).

Where E1 and E2 are the cutoff potentials in cyclic voltammetry, i(E)d(E) is the total voltametric charge obtained by integration of the positive and negative sweeps in the cyclic voltammograms, v is the scan rate and A is the area of the polymer film. Since the diffusion of supporting anion had same time to intercalate into the electrode at both low and scan rates, the specific capacitance values using equation 1 was found as approximately same value (32 mF cm⁻²). It can be observed that the measured capacitance value was constant as the scan rate increased.

\[ C_{sp} = \frac{\int_{E1}^{E2} i(E)d(E)}{2vA(E2 - E1)} \]  
(Equation 1)

Figure 1 (a) The capacitive effect of polymer film (potential range between 1.2 and -1.2 V with 50mVs⁻¹ scan rate) (b) CV characteriztion of polymer with different scan rates.

Secondly, the polymer film was scanned with different scan rates from 25 mVs⁻¹ to 200 mVs⁻¹ with an increment of 25 mVs⁻¹ (Figure 1(b)).It was found that the peak currents for the film increase linearly with increasing scan rate, indicating non-diffusional redox processes, and well-adhered electroactive polymer film on the working electrode surface (Figure 1(b)).

\[ C_{CV} = \frac{I}{v} \]  
(Equation 2)

The voltammetric capacitance \( C_{CV} \) of the polymer film can be obtained from the cyclic voltammograms based on the following equation where \( v \) is the voltage scan rate and \( i \) is the...
current. At a scan rate of 50 mVs$^{-1}$, a maximum $C_{\text{CV}}$ value of 55 mF cm$^{-2}$ was obtained. With reference to this figure, the most capacitive behaviour was seen on approximately 0.2 V potential value. Such a big capacitance value may be explained on the basis of charge saturation effect taking place at the end of the doping process [37]. (Figure 2(b)).

EDOT monomer was also electrodeposited on electrode with different charge value with chronocapamperometric method such as 5 mC, 10 mC, 15 mC and 20 mC respectively to estimate the doping level of PEDOT polymer film. CV characterization of these polymer films which have different charge values at a scan rate of 50 mVs$^{-1}$ were displayed in Figure 3(a).

![Figure 3(a)](image)

**Figure 3 (a)** The capacitive effect of polymer film (potential range between 1.2 and -1.2 V with 50 mVs$^{-1}$ scan rate). (b) The capacitive effect of polymer film (potential range between 1.2 and -1.2 V with 50 mVs$^{-1}$ scan rate).

The charge density $Q_d$ required for the formation and deposition of the oxidized PEDOT film from monomer can be determined experimentally. $Q_d$ corresponds to $(2+\gamma)$ electrons per EDOT where $\gamma$ is the number of electrons per EDOT required for switching. For doping level the maximal quantity of oxidized polymer ($Q_{\text{fmax}}$) is needed. $Q_{\text{fmax}}$ value was found from the integration of oxidized part of during cyclic voltameter. In this process doping level of polymer can be calculated to following formula:

$$Q_{f_{\text{max}}} = \left(\frac{\gamma}{\gamma + 2}\right)Q_d$$  \hspace{1cm} (Equation 3)

From equation 3, the $Q_{\text{fmax}}$ increase linearly with polymerization charge of polymer film with a slope of $\gamma / (2+\gamma)$. $\gamma$ value was found as 0.41 (Figure 2-b). This value agrees with those determined for polythiophene and its derivatives as reported in the literature value is higher than the reference value (0.33) [20]. This phenomenon is most probably related to ionic liquid medium. Ionic liquid increased the doping level of polymer film in our work.

Electrochemical impedance spectroscopy was also tested for the PEDOT electrode in this work. Nyquist plots of polymer film with different charges changes depending on the polymerization charges indicating ohmic resistance of polymeric films and ion transportation (Figure 4(a)). The low frequency capacitance $C_L$, which is related with frequency dependence of charging processes, can be calculated from the charge saturation region observed at low frequency. The capacitances value increase linearly with the polymerization charge of polymer film, as shown in Figure 4(b). In order to ascertain the performance of PEDOT electrode material for supercapacitor applications, galvanostatic charge discharge cycles were analysed for PEDOT film with various current densities. The specific capacitance ($C_{sp}$) of a material can be

![Figure 4(a) Nyquist plots of PEDOT films having different polymerization charges (b) Plots of low frequency capacitances from impedance spectroscopy versus polymerization charge at 0.4 V.](image)
estimated from charge discharge (CD) and as well as CV cycling. When charge-discharge method was used, the specific capacitance can be calculated according to Eq. 4

$$C_{sp} = \frac{It}{AV}$$  
(Equation 4)

where $I$ and $t$ are the discharge current and time, respectively. $V$ is the potential range and $A$ is the area of polymer on Pt electrode.

![Graph showing the effect of electrolyte on specific capacitance.](image)

Figure 5. Galvanostatic charge discharge characteristics of PEDOT electrode at different electrolytes at various current densities in 0.1 M LiClO$_4$ and ACN solvent.

Consistent with CD results, the specific capacitance decreased as the current density increased and the specific capacitance of the electrode at the current densities of 2, 3, 4 and 5 mA cm$^{-2}$ were 171, 79, 66, 68, respectively (Figure 5).

IV. Conclusion

Electrochemically synthesize PEDOT polymer film has good stability and reversible redox process. The specific capacitance value of PEDOT was found as 33 mF cm$^{-2}$ for a polymer film (5 mC).

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The experimental and Theoretical Studies of the Characteristics of LSPR Peaks of Metal Nanoparticles Controlled by Ar Ambient Gas Pressure for the Efficiency in the Solar Cells

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Abstract— In this study, Silver (Ag) nanoparticle thin films were deposited on microscope slide glass substrate by Pulsed Laser Deposition (PLD) in Argon (Ar) background gas pressure. Vacuum chamber can be evacuated down to $3 \times 10^{-7}$ mbar and then experimental works can be carried out using an Ar ambient gas pressure. Atomic Force Microscopy (AFM) analyse has shown that the deposition rate was decreased due to the collisions of Ag particles in the shrinking plasma by filling of Ar gas into the vacuum chamber. According to the absorption spectra taken by UV-VIS spectrometer, the wavelength, where the Localized Surface Plasmon Resonance (LSPR) was observed, which was shifted towards to the lower wavelength region as Ar background gas pressure was increased. The obtained spectra for Ag thin film nanoparticles was theoretically analysed and figured out by using a BEM (Boundary Element Method) simulation programme. In this study, experimental spectrum and simulation data for metal nanoparticles were acquired and compared, both are in well agreement. As a result of the release of Ar gas into vacuum chamber, the interparticle distance was increased and the changes occurred on the shapes of Ag nanoparticles. This has shown that LSPR wavelength can be tuned by adjusting the size of metal nanoparticles depending on Ar ambient gas pressure.

Keywords — Nanoparticle, Gas Pressure, Thin Film, BEM, PLD

I. INTRODUCTION

Recent years, the nanoscale noble metal particles have attracted a great amount of interest due to their unique optical properties not found in their bulk counterparts or in molecules [1, 2]. When the noble metal nanoparticle is exposed to the light, the excited plasmons in nanoparticle that oscillate with the electromagnetic field of light. This phenomena is called as Localised Surface Plasmon Resonance (LSPR). If the wavelength of light is larger than the nanoparticle diameter, LSPR occurs [3-6]. The silver nanoparticles among the plasmonic metals which is in group 11 metal and leads to polarization of electrons line up in $d^{10}$ orbit [7]. It has many application fields such as catalysis, energy storage, photovoltaics, optical nanosensors, surface enhanced spectroscopy [8-11].

The plasmonic nanoparticles are used in the light trapping method to increase the efficiency of the thin film solar cells [12]. The metal nanoparticles embedded into the interface of p-n junction of the solar cells which lead to absorption of more photons in the active layer with the effect of LSPR and prevent the recombination of charge carriers in the active layer. LSPR depends significantly on the nanoparticle size, shape, height, particle density, inter-particle distance, surrounding medium and the dielectric constant of the substrate [1, 2, 13].

Thin film coating techniques have significantly effect on the morphology of the thin film nanoparticles. Particularly, PLD technique [14] has many parameters that can be easily controlled during the deposition process of the nanostructures [15-25]. The nanoparticle size, nanoparticle density and the inter-particle distance can be controlled by background gas pressure in PLD [21]. Therefore, LSPR peak is tunable over the desired region in the solar spectrum.

In this study, experimental and the simulation results were compared to prove the accuracy of the LSPR wavelength of Ag nanoparticle thin films that were grown depending on the Ar ambient gas pressure. LSPR properties of metallic nanoparticles were simulated by using a Boundary Element Method (BEM) [26].

II. EXPERIMENT

Ag nanoparticles were deposited on the microscope slide glass substrate by PLD at room temperature (RT). An Nd:YAG laser system was used to ablate and deposite thin films and laser system was operated to deliver laser pulses with 5 ns duration, 40 mJ energy per pulse at 1064 nm wavelength, 10 Hz repetition rate. A 99.95% pure Ag metallic target material (Kurt Lesker) in one inch in diameter was used in experiments. The distance between the target material and the substrate was set to 45 mm. The 40 cm focal length biconvex
lens was used to focus the laser beam onto the target material. To avoid damage the target, and to form a uniform and smooth thin film, the target material and the substrate holder were rotated at a certain-constant speed.

The microscope slide glasses were first cleaned with soap foam, subsequently was bath in acetone and isopropyl alcohol for fifteen minutes for each chemicals. The cleaning procedure was carried out in an ultrasonic bath, and then the substrates were dried in a N₂ flow.

The vacuum chamber was evacuated to 3×10⁻⁷ mbar before the experiment. Afterward, Ag nanoparticles were grown in Ar gas pressure of 1.0×10⁻³ mbar and 7.5×10⁻⁴ mbar, respectively.

The morphology of the Ag thin films deposited on a microscope glass substrate was analysed by AFM techniques. The optical absorption spectra of the Ag thin films were measured using an UV-VIS spectrophotometer (JASCO, V-670 Spectrophotometer, JAPAN).

III. RESULTS AND DISCUSSION

Ar used in the experiment as an inert gas which does not react with the ablated Ag particles. The ambience in the Ar gas pressure of 1.0×10⁻³ mbar that is close to vacuum conditions [20]. When the high-energy laser pulses focuses on the surface of target material, the ablated Ag particles form the plasma [22]. The plasma plume expands freely in the Ar gas ambient [17, 18, 25] of 1.0×10⁻³ mbar. Ag nanoparticles collide several times with the surrounding gas atoms at low density and their kinetic energy are not incurred a great loss [27]. So, the velocities of Ag nanoparticles are still high. Also, the mean free path of nanoparticles is long [11, 23, 24], and the deposition rate is high [11].

![Fig. 1 Plasma plume of Ag nanoparticles formed in Ar gas ambience of 1.0×10⁻³ mbar](image1)

![Fig. 2 AFM image of Ag nanoparticles formed in Ar gas ambience of 1.0×10⁻³ mbar in 5μm×5μm area](image2)

When Ar gas pressure is increased to 7.5×10⁻⁴ mbar, the ablated Ag particles collide strongly with surrounding dense Ar gas atoms, thus the kinetic energies of nanoparticles are decreased rapidly [27]. A portion of Ag nanoparticles scatters backward and escape to the vacuum environment or stops [22]. Therefore, the number of particles reaching on the substrate are reduced and the mean-free path of the ablated particles decreases [20]. It can be seen of the volume of the plasma plume is became smaller [15, 25] as presented in Fig.3.

![Fig. 1 Plasma plume of Ag nanoparticles formed in Ar gas ambience of 7.5×10⁻⁴ mbar](image3)

![Fig. 4 AFM image of Ag nanoparticles formed in Ar gas ambience of 7.5×10⁻⁴ mbar in 5μm×5μm area](image4)

Because of a small amount of particles reach on the substrate, the density of particles on the surface is reduced. Ag nanoparticles reaching on the surface that have no longer high kinetic energy. They move slowly as similar to moving particles in decreasing substrate temperature [16]. Since the diffusion length of the nanoparticles is low on the substrate surface [11, 19], the aggregation of Ag nanoparticles is limited and therefore, the size of particles are became smaller [11, 21]. Ag nanoparticles grown in the Ar gas pressure of 7.5×10⁻⁴ mbar that have smaller size as shown in the AFM image in Fig. 4. Also, inter-particle distance was increased.
When a plasmonic nanoparticle is subjected to light, due to the fact that the conduction electrons in the nanoparticles are confined in three dimensions, the electric field of the light induces a movement of the free electrons. The conduction electrons accumulate at the surface of nanoparticles a called the "plasmon".

Fig. 5 Oscillating motion of plasmons induced by the electric field of light

The plasmons are oscillates by the electric field of light at a certain frequency which lead to light to be confined into the nanoscale size of the metallic particle. The frequency where LSPR (inversely proportional to the oscillation wavelength) is strongly dependent on the morphology of nanoparticles [3-6]. The changes on the morphological parameters lead to the tuning of the wavelength of LSPR between UV to IR region [28].
According to the simulation results of the extinction spectra of Ag thin film nanoparticles, LSPR peaks for Ar gas pressure of 1.0 × 10⁻³ mbar and 7.5 × 10⁻³ mbar which were located on the 655 nm (purple solid line) and 555 nm wavelength (turquoise dashed line), respectively. Consequently, the simulation results are in agreement with experimental results.

IV. CONCLUSION

LSPR peaks of Ag nanoparticles grown in the Ar gas pressure which were located on the longer wavelength that can be attributed to the larger particle size. As the gas pressure is increased, the size of Ag particles were reduced and the wavelength where LSPR shifted to the shorter region. These experimental results are consistent with the results which was obtained by using BEM simulations. The Ag nanoparticles can be embedded into the active layer of the thin film solar cell by PLD. The absorption region of the active layer can be made to be tunable by controlling Ar gas pressure. Thus, it can be contributed to the efficiency of thin film solar cells by PLD technique.

ACKNOWLEDGMENT

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REFERENCES

Investigation of the Effect of Nanoclay Inclusion on Charpy Impact Behavior of the Glass Fiber Reinforced Composite Laminate

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Abstract—The progression in technology requires improved material performance to satisfy market necessities. One of the promising ways for the improvement of composite materials is the addition of some additives or fillers. Due to scientific and industrial relevance, the investigation of the effects of additives into material have become popular subject in the current decade. The current study presents the effects of nanoclay particles on the impact behavior of glass fiber reinforced composite laminates. Nanostructured composite laminates are fabricated by a vacuum bag molding after hand layup technique using different weight percentages of nanoclay. Charpy impact tests are performed to determine the impact behavior of fabricated laminates. The results show that the incorporation of nanoclay particles have significant effects on the Charpy impact behaviour.

Keywords—nanocomposite, nanoclay, glass fiber, epoxy, impact

I. INTRODUCTION

Fiber reinforced polymer composite materials have attracted significant interest in the past few decades due to their outstanding performance-to-weight ratio in relation to conventional engineering materials [1]. Fiber reinforced polymer composites also exhibit better damping characteristics, good fatigue resistance and high resistance to corrosion [2]. With these outstanding properties, fiber reinforced polymer composites have become promising materials for the application of aerospace, automotive, marine and defense industries. However, fiber reinforced polymer composites are susceptible to out-of-plane impact damage resistance which can cause significant reductions in strength and, in turn, leads to heavier designs to meet safety requirements [3]. One of the methods to improve the impact damage resistance of fiber reinforced polymer composites is the addition of small amount of nanoparticles into the matrix of composites [4].

The introduction of nanoparticles into the resin constituting the composites matrix is a relatively new advancement in the field of polymer composites. Over the last two decades, several researches have reported that the addition of small amounts of nanoparticles, such as carbon nanotubes, nanometal oxides, graphene and nanoclays, lead to remarkable improvements in mechanical, thermal, morphological, electrical and optical properties of polymer composite materials without compromising on toughness, density and manufacturing process [5]. Among different types of nanoparticles, nanoclays have received significant attention due to its low cost and easy availability [5]. Numerous researchers have investigated the various properties and characteristics of nanoclay reinforced polymer composites. The range of properties in which the introduction of nanoclay yields improvements over neat polymers used composite materials is much more than the expected. The advantages of nanoclay filled composites are generally demonstrated with the improvements in mechanical and thermal properties such as quasi-static tensile and flexural properties, fracture resistance, thermal degradation resistance. However, the mechanical properties of nanoparticle reinforced polymer composite are very low compared to fiber reinforced polymer composites [6]. In recent years, an increasing interest has emerged on the development of ternary hybrid composites in which continuous fibers and nanoparticles are simultaneously added to polymer matrix. In particular, some studies have focused on the improvement of mechanical properties of fiber reinforced polymer composites by introduction of nanoclay to the epoxy matrix. Haque et al. [7] investigated the influence of nanoclay content on fracture behavior, mechanical and thermal properties of glass fiber reinforced polymer matrix composites. Siddiqui et al. [8] analyzed the mechanical properties such as compact tensile, flexural, fracture and Izod impact behavior of carbon fiber reinforced nanoclay based polymer matrix composites. Chowdary and Kumar [9] prepared glass fiber reinforced polyester matrix composites with five different wt% of nanoclay in order to assess the effect of nanoclay content on tensile and flexural behavior. Chandradass et al. [10] outlined the effect of nanoclay dispersion on tensile, flexural, interlaminar shear strength, vibration, impact and thermal characteristics of glass fiber reinforced vinyl ester polymer composites. Sivasaravanan et al. [11] presented the tensile, impact and hardness characteristics of nanoclay added glass fiber reinforced polymer matrix composites. Iqbal et al. [4] revealed the impact damage resistance of carbon fiber reinforced composite based on nanoclay filled epoxy matrix. Reis et al. [12] explored the influence of nanoclay content on impact response of Kevlar fiber reinforced epoxy composites
to determine the ideal amount (wt.%) of nanoclay for the best impact response.

Despite the large number of publications on polymer-clay nanocomposites, there is very little literature about the effects of adding nanoclay to polymer on Charpy impact behavior of glass fiber reinforced polymer composites. Therefore, the aim of this work is to analyze the variation of Charpy impact behavior of glass fiber reinforced nanoclay based epoxy matrix composite with respect to the nanoclay weight fraction. A group of glass fiber reinforced nanoclay based epoxy matrix composites with clay concentration up to 3 wt% have been prepared using hand lay-up technique.

II. MATERIALS AND METHODS

A. Materials

Epoxy resin (MOMENTIVE-MGS L285) and hardener (MOMENTIVE-MGS H285) were supplied by DOST Chemical Industrial Raw Materials Industry, Turkey. Montmorillonite nanoclay with 35-45 wt% dimethyl dialky (C14-C18) amine was obtained from Grafen Chemical Industries, Turkey. Plain weave E-glass fabric (01266 0800 TF970) with areal density of 202 g/m² manufactured by Hexcel Corporation, Italy was used as the main reinforcement phase. Firstly, epoxy/nanoclay mixture with different clay contents (1, 2, 3 wt%) were prepared by adding the weighted epoxy and nanoclay in a suitable beaker and mixing with a mechanical stirrer. Then hardener was added to the mixture at an epoxy to hardener weight ratio of 100:40 and mixed thoroughly again. The density and thickness values of glass fiber fabric, nanoclay and matrix are presented in Table I.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Density (g/m²)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass fabric</td>
<td>202</td>
<td>0.15</td>
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<tr>
<td>Nanoclay</td>
<td>200-500</td>
<td>1-10</td>
</tr>
<tr>
<td>Epoxy</td>
<td>1.18</td>
<td>-</td>
</tr>
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</table>

B. Fabrication of Specimens

The preparation of nanoclay filled epoxy based glass fiber reinforced composites was carried out by hand layup method in Fig. 1. Twelve plies of glass fabric were cut into 300 mm × 250 mm. A thin release agent film was applied on the surface of mold plates. A layer of resin (epoxy/nanoclay/hardener) mixture was deposited on bottom mold surface. First ply was placed over mold and resin mixture was applied with the help of a brush until it was entirely wetted. Second ply was placed on the first one and resin mixture was applied until it became entirely wet. This operation was repeated until twelve plies were stacked. After completion of all plies, the top of entire fabric stack was covered with top mold plate and whole assembly was placed in a hot press. The laminate was cured at a temperature of 80°C and a pressure of 4 MPa for 3 hours. After the plate was cured, it was removed from the mold.

C. Mechanical Tests

Charpy impact tests were conducted following ISO 179/92 standard. A Köger 3/70 Charpy impact test machine, shown in Fig. 2, was employed for the tests. Both notched and unnotched specimens with a dimension of 55 mm × 10 mm were prepared and subjected to flatwise and edgewise impact loadings, respectively. For each laminate structure and test configuration (edgewise and flatwise), five specimens were tested. All tests were performed at standard weather conditions. The absorbed impact energy and impact toughness of specimens were determined according to following equations:

\[ E = E_a - E_b \]

where, \( E, E_a, E_b, \) and \( b \) represent the absorbed impact energy, potential energy of the weighted pendulum before and after impact (shown in Fig. 3), impact toughness, thickness and width of the test specimen, respectively. Average values and standard deviations for the absorbed impact energy and impact toughness were used to assess the effect of nanoclay.
III. RESULTS AND DISCUSSION

The Charpy impact test was used to measure the impact energy absorbed by the specimens. The impact energy values for notched (edgewise impacted) and unnotched (flatwise impacted) specimens were plotted against nanoclay contents in Fig. 4 and 5, respectively. Compared to impact energy of glass fiber reinforced epoxy composite, the achieved increase in absorbed impact energy of the notched specimens were 3%, 19% and 10% for 1 wt%, 2 wt% and 3% nanoclay filled glass fiber reinforced epoxy composites, respectively. The results showed that the addition of nanoclay into glass fiber reinforced epoxy became more significant at low contents and the 2 wt% clay content exhibited the highest impact energy absorption. At higher content, the addition of nanoclay was not so effective in improvement of impact energy absorption. Probably, it can be attributed to the agglomeration of nanoclay particles which resulted with a weak interfacial adhesion.

For the unnotched test specimens, the variation in absorbed impact energy of the notched specimens were 8%, 11% and -19% for 1 wt%, 2 wt% and 3% nanoclay filled glass fiber reinforced epoxy composites, respectively. The addition of nanoclay became more significant at low contents and the 2 wt% clay content exhibited the highest impact energy absorption by 11% improvement. At higher content, the addition of nanoclay was derogated the impact energy absorption. The agglomeration of nanoclay particles can be the reason of decrease. In the literature, several similar results were reported for effect of nanoparticles on mechanical properties of composite materials [13].

IV. CONCLUSIONS

The Charpy impact properties of nanoclay filled epoxy based glass fiber reinforced composites were studied. The impact properties were measured by the impact energy absorption of notched and unnotched specimens. For the notched specimens, addition of nanoclay provided an improvement in impact energy absorption regardless of clay content. The improvement in impact energy absorption was increased to a maximum by 19% at 2 wt% nanoclay content and showed diminishing improvement for further addition of nanoclay. For the unnotched specimens, the improvement in impact energy absorption was increased to a maximum by 11% at 2 wt% nanoclay content. However, further addition of nanoclay decreased the impact energy absorption. The results suggested that the impact energy absorption of glass fiber reinforced composites could be improved by the addition of small amounts of nanoclay.

REFERENCES


The Effect of Nanoclay on Tensile and Flexural Behavior of Glass Fiber Reinforced Composite Laminates

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Abstract—In this study, the effect of nanoclay particles on tensile and flexural properties of glass fiber reinforced polymeric composite laminates are investigated. The nano-structured composite laminates are fabricated by hand layup process using different weight percentages of nanoclay additive. The nanoclay particles are dispersed in epoxy resin using mechanical stirring. The tensile and flexural behavior of fabricated composite laminates are measured by performing uniaxial tensile and three-point bending tests. The present results show that the incorporation of nanoclay yields a substantial effect on the tensile and flexural properties of glass fiber reinforced composite laminates.

Keywords—nanocomposite, nanoclay, glass fiber, epoxy, impact

I. INTRODUCTION

The fiber reinforced polymeric composites have already proven their worth as weight-saving materials having high strength. Because of that, application areas of polymeric composites have extended day by day. Nowadays, polymeric composites have become one of the most popular materials in several engineering applications such as sporting goods, household appliances, automotive, aerospace, marine and defense industries. The desire to improve the performance, reliability and functionality of polymeric composite materials with increasing demand in the market necessities is directed to develop and implement new approaches in the fabrications of polymeric composite materials.

One of the ways to enhance the mechanical properties of polymeric composites is to improve the polymer matrix-dominated properties by incorporating some fillers or particles into the resin. The addition of particles, especially nanoparticles, into polymeric matrix is a newly developing area in the polymeric composite sector. Polymeric nanocomposites, where at least one of the dimensions of the particulate material is less than 100 nm, have shown significant improvements in mechanical, thermal, morphological, electrical and optical properties of polymeric composites [1]. Various types of nanoparticles, such as carbon nanotubes, nanometal oxides, graphene and nanoclays, are currently used as fillers in the polymeric composites. Due to substantial enhancement of mechanical properties with the addition of small amount of nanoclay and large natural abundance of nanoclay, nanoclay-polymer composites have engrossed great attention. Numerous researches have dealt with the effect of nanoclay on tensile, flexural, impact and fracture characteristics of polymer resins. In these investigations, variations of mechanical properties with respect to nanoclay loadings have been reported as increasing or decreasing.

However, the cited properties of nanoparticle reinforced polymer composite are so low that cannot be compared with the properties offered by fiber reinforced polymer composites [2]. In recent years, a new trend has developed toward the development of ternary hybrid composites by using continuous fibers and nanoparticles simultaneously in the same matrix system. Several studies have particularly dealt with the effect of nanoclay content on mechanical properties of fiber reinforced. Dorigato et al. [3] prepared glass fiber reinforced epoxy nanoclay composites and carried out a detailed investigation about the potential use of nanoclay-epoxy matrix for fiber reinforced composites. The quasi-static tensile and single edge notched bend tests were performed to determine effect of nanoclay on tensile and fracture toughness characteristics. Subramaniyan and Sun [4] sought the variation of compressive strength of glass fiber reinforced vinyl ester with the addition of nanoclay. Rahman et al. [5] explored the effect of nanoclay on thermal stability, tensile and flexural behavior of chopped glass fiber reinforced polypropylene composites. Mohan and Kanny [6] analyzed the effect of nanoclay content on short glass fiber reinforced polypropylene composites. Santiago et al. [7] revealed the changes of quasi-static tensile and dynamic compression properties with variations of nanoclay content. Chowdary and Kumar [8] studied the tensile properties of glass fiber reinforced polyester-nanoclay composites and reported the effect of nanoclay on tensile strength and modulus.

The present work focused on measurement of tensile and flexural properties of nanoclay filled epoxy based glass fiber reinforced composites and the investigation of effect of nanoclay content on tensile and flexural properties of glass fiber reinforced epoxy composites. Several glass fiber reinforced nanoclay filled epoxy based composite laminates with different clay concentrations have been prepared.
II. EXPERIMENTAL PROCEDURES

A. Materials

Epoxy resin (MOMENTIVE-MGS L285) and hardener (MOMENTIVE-MGS H285) provided by DOST Chemical Industrial Raw Materials Industry, Turkey were used to form matrix constituent. Montmorillonite nanoclay with 35-45 wt% dimethyl dialkyl (C14-C18) amine was obtained from Grafen Chemical Industries, Turkey. E-glass fabric (01266 0800 TF970) produced by Hexcel Corporation, Italy was employed as the main reinforcement of nanocomposite. The fabric was characterized by plain weave and areal weight of 202 g/m². The epoxy/nanoclay mixture with different clay contents (1, 2, 3 wt%) were prepared by stirring the weighted epoxy and nanoclay with a mechanical stirrer. After that the hardener was added to mixture of epoxy/nanoclay using epoxy-to-hardener weight ratio of 100:40 and mixed thoroughly again. The density and thickness values for epoxy resin, nanoclay and glass fabric were presented in Table I.

Table I: The Physical Properties of Reinforcements and Epoxy Resin

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Density</th>
<th>Thickness</th>
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<tbody>
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<td>Glass fabric</td>
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</tr>
<tr>
<td>Epoxy</td>
<td>1.18 g/m³</td>
<td>-</td>
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</table>

B. Fabrication of Specimens

Hand layup technique, shown in Fig. 1, was used for the fabrication of nanoclay filled epoxy based glass fiber reinforced composites. At first, a thin release agent film was deposited on the surface of mold plates. First fabric layer was put on mold and fully soaked with resin mixture (epoxy/nanoclay/hardener) using a brush. Second fabric layer was laid on the first one and resin mixture was applied until it became entirely wet. This operation was repeated until twelve layers were stacked. After stacking procedure, top mold plate was placed on fabric stack and the whole assembly was compacted in a hot press. The laminate was cured at a pressure of 4 MPa and a temperature of 80°C for 3 hours. Finally, composite laminate was demolded.

C. Mechanical Tests

In order to investigate the effect of nanoclay on mechanical properties of epoxy based glass fiber reinforced composites, three-point bending and uniaxial tensile tests were performed. Five specimens were prepared for each test of each composite configuration and averages of results were provided. The tests were exerted at standard humidity and room temperature conditions using a 50 kN Shimadzu AG-X series universal testing machine.

The uniaxial tensile tests were carried out in accordance to the ASTM D3039 standard specifications. The three-point bending tests were conducted according ASTM D790 standard. The span-to-depth ratio of specimens were used as 32:1 and specimen dimensions were 200 mm in length and 12.7 mm in width.

III. RESULTS AND DISCUSSIONS

The tensile strengths of the prepared composite samples were determined by conducting uniaxial tensile test. The variation of tensile strength values against nanoclay contents was presented in Fig. 2. Compared to tensile strength of glass fiber reinforced composite without nanoclay content, the increase in tensile strength were 8%, 4% and 1% for 1 wt%, 2 wt% and 3% nanoclay filled epoxy based glass fiber reinforced composites, respectively. As can be seen in figure, the enhancement of tensile strength at low nanoclay contents was more significant and the 1 wt% clay content yielded the highest tensile strength. At higher content, the introduction of nanoclay was not so effective in improvement of tensile strength. Probably, it can be attributed to the agglomeration of nanoclay particles which resulted with poor adhesion. Several similar results were reported in the literature [9].

Fig. 2: Variation of tensile strength according to nanoclay content

Flexural strength and modulus of nanoclay filled epoxy based glass fiber reinforced composite laminates were plotted against nanoclay contents in Fig. 3 and 4, respectively. As seen in the figure, all nanoclay filled composites showed lower flexural strength and modulus compared to the composites without nanoclay. The addition of nanoclay into glass fiber reinforced epoxy composites resulted with decreases in both flexural strength and modulus from 327 MPa to 280 MPa and 15 GPa to 13 Gpa, respectively. The declines in flexural strength and modulus with addition of nanoclay can be seemed as a result of debonding of nanoclay and epoxy, poor dispersion.
and the presence of multiple micro-sized voids due to excess stretching fibers. The increase in the rate of decline with respect to increase in nanoclay content can be attributed to agglomeration of nanoclay particles.

The enhancement in tensile strength was reached to a maximum by 8% at 1 wt% nanoclay content and showed diminishing improvement for further addition of nanoclay. The addition of nanoclay resulted in lower flexural modulus and strength compared to the composites without nanoclay content. The rate of decline in flexural modulus and strength were increased with respect to increase in nanoclay content. The maximum decrease in flexural modulus and strength were 17% and 14% for 3 wt% nanoclay content. The declines in flexural modulus and strength can be attributed to poor adhesion and the presence of multiple micro-sized voids due to excess stretching fibers. The results showed that the tensile strength of glass fiber reinforced composites could be improved by the addition of small amounts of nanoclay.

IV. CONCLUSIONS

Fiber reinforced hybrid nanocomposites were fabricated using glass fiber and nanoclay filled epoxy. The composites were prepared with the introduction of different weight percentage of nanoclay (1 wt%, 2 wt% and 3 wt% of weight of matrix). The uniaxial tensile and three-point bending tests were performed to investigate the effect of nanoclay on tensile and flexural properties of epoxy based glass fiber reinforced composites. The introduction nanoclay yielded an improvement in tensile strength regardless of nanoclay content.

REFERENCES

Densification and Mechanical Behavior of Alumina Matrix Nano Metal Composites

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Abstract—In the present work, Al₂O₃-Ni and Al₂O₃-Co powder mixtures were prepared with 3 vol. % metal ratios by the heterogeneous precipitation method. To increase the green strength, PPC was used as a binder while preparing green compacts. Specimens are pressureless sintered at 1550°C for 2h in reducing atmosphere condition. The structural and mechanical properties of the composites were characterized by XRD, SEM, Vickers Indentation technique and three-point bending test. The effects of 3 vol. % Ni and 3 vol. % Co to the microstructure and mechanical properties were investigated by comparison.

Keywords—Alumina, Composite, Microstructure, Hardness, Toughness, Strength.

I. INTRODUCTION

The structural applications of alumina ceramics (Al₂O₃) are restricted due to its brittle nature, low tensile strength and low thermal shock resistance [1]. Incorporation of ductile metal particles into the alumina matrix is an effective way to overcome these problems [2]. Especially, alumina/metal nanocomposites are of great interest because of the superior properties they have such as hardness improvement [3]. The particular case of Al₂O₃/nNi system has been widely studied up to the present [2,4,5]. It is shown that the fracture strength and hardness of the alumina clearly enhanced by incorporating Ni nano particles into matrix [5]. Al₂O₃/nCo system is another choice for this concept due to the attractive properties of cobalt like high melting temperature (1495°C) and better wetting ability with Al₂O₃ in comparison with Ni [6,7].

In ceramic processing, binders are often used to improve the strength of the green compacts and sometimes the relative density [8]. There are various organic binders which are either soluble in water or organic solvents, like PVA (polyvinylalcohol) and PEG (polyethylene glycol). In this work, polypropylene carbonate (PPC) was preferred as a binder because it burns out completely during the sintering cycle in reducing atmosphere conditions[9].

To prepare of the composite powders, the heterogeneous precipitation method was chosen as fabrication method that provides homogeneous metal particle dispersion [2,10]. The metal ratios of both Ni and Co were adjusted as 3 vol. % in the final composites and the specimens were conventional sintered at 1550°C. By comparing the effect of Ni and Co reinforcement on the alumina ceramic, densification, and mechanical properties were investigated.

II. EXPERIMENTAL PROCEDURE

In the present work, the starting materials were α-Al₂O₃ powder with average diameter of 0.60 µm (Almatis Calcined Alumina, Germany), nickel nitrate hexahydrate and cobalt nitrate hexahydrate, (Ni(NO₃)₂·6H₂O) (BDH Chemicals Ltd., Poole, England, 98% purity) (Co(NO₃)₂·6H₂O) (Sigma-Aldrich, 98% purity), ammonium bicarbonate (NH₄HCO₃) (Sigma Aldrich, 99% purity), polyacrylic acid as dispersant (Darvan 821A from MSE Tech Co. Ltd., Turkey) and finally PPC as binder (Qpac 40, Empower Materials, USA).

Al₂O₃, an appropriate amount of metal nitrate hexahydrate that provides 3 vol. % metal content in the final composite and 0.5wt% (equivalent to Al₂O₃ weight) polyacrylic acid were first mixed in distilled water and ball milled for 24 hours with alumina balls (ball: Al₂O₃ powder ratio of 10:1 by weight). 1.0 M aqueous solution of NH₄HCO₃ (the precipitation agent) was added dropwise into the 24h ball milled slurry under vigorous stirring on a magnetic stirrer. The reactions were given by the following equations [2,10,11]:

3Ni^{2+} + 6HCO_{3}^{-} + H_{2}O -→ NiCO_{3}•2Ni(OH)_{2}•2H_{2}O ↓ + 5CO_{2} ↑

3Co^{2+} + 6HCO_{3}^{-} + H_{2}O -→ CoCO_{3}•2Co(OH)_{2}•2H_{2}O ↓ + 5CO_{2} ↑

To guarantee the completion of above reactions during precipitation, an excess amount of NH₄HCO₃ was used and the pH value of the slurries was kept between 8-9. After precipitation, the slurries were filtered and washed with distilled water and ethanol. After the drying in air for a day, the dried powders were first calcined in air at 500°C for 2h and then reduced in a 90%Ar/10%H₂ atmosphere at 700°C/4h for Ni and at 950°C/2h for Co [9,11]. The reducing cycles were 5°C/min for both calcination and reduction treatment and then cooled down to room temperature in the furnace. Following these heat treatments nano metal coated Al₂O₃ composite powder can be obtained. Monolithic Al₂O₃ powder was prepared under the same conditions to compare the final properties with composites. The reduced powder mixtures and the monolithic alumina powder were sieved down to 90 µm and pressed in to a rectangular prism form in a 40x50 mm steel mold under the uniaxial pressure of 100 MPa. However, the pressed samples were cracked and broke up easily while removing from mold.
In order to increase the green strength, 3 wt. % and 2 wt. % PPC binder was added to the alumina and composite powders, respectively. For uniform mixing of PPC, a stoke solution was prepared with acetone and acetone was evaporated under vigorous stirring from PPC solution-powder mixture. The powders were dried and sieved again. The pressing procedure was repeated and the specimens in required form and strength were obtained. All the specimens were pressureless sintered in a vertical tube furnace at 1550°C for 2h in reducing (90%Ar/10%H₂) atmosphere. Binder burn out was carried out during sintering at 350°C. The prismatic bars were cut from the pieces after sintering with 3 mm width, 2 mm thickness, and 40 mm length.

X-ray diffraction (XRD) patterns were obtained at a scanning rate of 4°/min with a 2θ range from 5° to 70° by a Bruker® D8 Advance diffractometer. The Archimedes’ water replacement method was used to measure the bulk density of the sintered specimens. Scanning electron microscope (SEM) (Philips XL 30 SFEG) was employed to characterize the microstructure of the samples. The samples were grounded and polished down to 0.5 μm to see the grains and metal phases clearly in SEM analysis and to eliminate the effect of surface flaws on mechanical properties. The samples were thermally etched to reveal the grain boundaries at 1400°C/0.5h in the sintering conditions. Hardness was measured by an Instron® Wolpert Testor 2100 equipped with a diamond pyramid Vickers indenter. Loading time and load was selected as 10 s and 5 kg, respectively. Fracture toughness, Kc, was determined using the Vickers indentation technique using 10 s and 10 kg load. Flexural strength was measured by three-point bending test with a load span of 20 mm and a loading rate of 0.2 mm/s.

III. RESULTS AND DISCUSSION

As summarized in the experimental section, the powder mixture was calcined, reduced, and sintered. With calcination at 500°C/2h in air, the crystallization to discrete nano sized metal oxide phase occurred. By heat treatment at 700°C/4h and 950°C/2h in reducing atmosphere, metal oxide particles were all reduced to nano sized Ni and Co particles, respectively. The calcination and reduction parameters were determined according to Guo-Jun Li and his co-workers study [2]. Fig. 1 shows the XRD patterns of Al₂O₃/3 vol. % Ni composite after a) calcination, b) reducing, and c) sintering. In these figures, only Ni and NiO peaks are labelled for clarity, not labelled peaks are Al₂O₃’s. When the patterns are analysed, it can be seen that after reducing only Ni peaks are present and after sintering at 1550 °C, the peaks of Ni metal phase become more pronounced. This increase in peak intensity is attributed to the growth of metal phase from nano sizes (about 50 nm) to submicron sizes (from 100 nm to 500 nm). Fig. 2 shows the XRD patterns of Al₂O₃/3 vol. % Co composite after a) calcination, b) reducing, and c) sintering. Similar to Ni containing composites, CoO peaks were replaced by Co peaks after reducing and the intensities of Co peaks increase after sintering at 1550°C due to Co particle growth.

Fig. 3 shows SEM micrographs of thermally etched monolithic alumina and the composite specimens in backscattered electron mode. Metal particles and Al₂O₃ grains seem brighter and darker, respectively. For both composites, metal particles were spherical and dispersed homogeneously in the matrix. Also, it can be seen that metal particles were generally located at the triple junctions and at grain boundaries.

![Image](313x596 to 553x719)

![Image](510x423 to 549x557)

![Image](510x423)

Table 1 shows the experimental results of the % relative density, Vickers hardness, toughness and flexural strength measurements of the specimens. The densities were first measured by Archimedes’ water replacement method and theoretical densities were calculated by the rule of mixtures before determining the relative densities. The highest relative density was obtained for the monolithic alumina, 98.9 %. For both Ni and Co composites, the relative density was 97.8 % which is lower than monolithic aluminas. The density difference can also be seen from SEM micrographs in Fig. 3. The decrease in density can be attributed to poor wetting of the metal phases, hence hindering the sintering of alumina [12]. It was reported that wetting ability of cobalt is better than nickel’s; still, it appears that their sintering behaviour is not different.

<table>
<thead>
<tr>
<th>Material</th>
<th>Relative Density (%)</th>
<th>Hardness (GPa)</th>
<th>Flexural Strength (MPa)</th>
<th>Vicker's Toughness MPa·m¹/²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>98.9±0.2</td>
<td>21.7±1.3</td>
<td>62.3±7.0</td>
<td>3.68±0.45</td>
</tr>
<tr>
<td>Al₂O₃/Ni</td>
<td>97.8±0.3</td>
<td>21.6±1.0</td>
<td>549±86</td>
<td>4.42±0.67</td>
</tr>
<tr>
<td>Al₂O₃/Co</td>
<td>97.8±0.3</td>
<td>21.9±1.1</td>
<td>588±82</td>
<td>4.67±0.96</td>
</tr>
</tbody>
</table>
Vickers hardness measurements as presented in Table I show that alumina and metal reinforced composites have equal hardness values. The soft character of metal phases would expect to decrease the hardness of the composites by the rule of mixtures. Also, lower relative densities of metal reinforced composites should result in decreased hardness for these materials. On the other hand, the small size of metal particles increases the hardness and compensates for the decrease in hardness [10]. As a result, similar hardness values are obtained for monolithic alumina and the composite specimens.

Strength ($\sigma_f$) of ceramic materials is determined by their fracture toughness ($K_c$) and defect size ($a$) [13]:

$$\sigma_f = \frac{K_c}{\sqrt{\pi a}}$$

It is desired that a structural ceramic material would have a high fracture toughness and a small defect size so that it would have a high tensile or bending strength [13]. From Table 1, it is seen that the highest strength is achieved for monolithic alumina, 62.3±70 MPa, even tough, they had lower toughness 3.68±0.45 MPa·m$^{1/2}$, compared to the composites. Monolithic samples had the highest relative density; therefore, they had the smallest defects and the highest strength. On the other hand, metal reinforced composites have similar densities; i.e. similar defect size. Since the defect sizes are similar, the strength is determined by fracture toughness of the material. Co reinforced composites have higher fracture toughness, 4.67±0.96 MPa·m$^{1/2}$, compared to Ni reinforced composites, 4.42±0.67 MPa·m$^{1/2}$. The mechanism for increasing the fracture toughness is believed to be a combination of the plastic deformation of the ductile phase ahead of the crack tip and the crack bridging at the wake of the crack. It appears that Co is a more effective reinforcement in order to enhance the fracture toughness of the alumina by using heterogeneous precipitation method. SEM observations reveal that Co particles were larger compared to Ni particles and the enhanced fracture toughness is attributed to these larger ductile particles. As a result of its higher toughness, the strength of Co reinforced composites is higher than that of Ni reinforced composites; 588±82 MPa and 549±86 MPa, respectively. In other words, a 5% increase in fracture toughness while keeping the defect size similar resulted in a 5% increase in strength.

IV. CONCLUSIONS

Al$_2$O$_3$-Ni and Al$_2$O$_3$-Co powder mixtures with 3 vol. % metal ratios were prepared successfully by the heterogeneous precipitation method and sintered at 1550°C/2h in reducing atmosphere. When the densification and mechanical properties of alumina were compared to the composites, the highest density was observed for Al$_2$O$_3$. Still, the hardness measurements showed that 3 vol. % metal phase reinforcement did not cause a decrease in hardness. Metal phase, specifically Co, increased the toughness of the material; however, due to smaller defect size accompanied by better densification, maximum strength is achieved in monolithic alumina.

ACKNOWLEDGMENT

The support of GTU Scientific Research Council #2015-A-33 project is greatly appreciated.

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Effects of Si and Mn on machinability and wear resistance of AS91 and AM90 magnesium alloys

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Abstract— This study investigates the effect of Silicon (Si) and Manganese (Mn) on AS91 (9% Al, 1% Si) and AM90 (9% Al, 0.5% Mn) magnesium alloys that are among important magnesium alloys wear resistance and machinability. Hardness of intermetallic phases found in the microstructure of magnesium alloys was observed to affect wear resistance and machinability. Mg-Si found in the microstructure of AS91 alloy was established to reduce machinability while intermetallic phase increased hardness and wear resistance. It was found that intermetallic phases (Mg17Al12, Mg2Si and Al4Mn) of AS91 and AM90 magnesium alloys had an impact on cutting forces and machinability and mechanical properties.

Keywords— Machinability, cutting force, surface roughness, wear, AS91, AM90 series magnesium alloys

I. INTRODUCTION

Today, there are numerous areas of use for magnesium and its alloys due to their characteristics, and these areas of use grow in number every day. Especially due to being among the lightest structure metals for their low density and high resistance characteristics, magnesium alloys gain importance in many fields, predominantly in logistics, automotive, and aviation sectors [1,2,3]. Their use in vast fields continues depending on improving certain characteristics. Some of such characteristics to be improved are their mechanical features, hardness, wear, and machinability. A large number of studies carried out on magnesium alloys were about obtaining different alloys and investigating the mechanical characteristics of such alloys [4,5]. Studies conducted on alloy properties affecting the improvement of wear characteristics of magnesium alloys and their correlation with machinability are quite low in number and insufficient. It is quite important to investigate the use of magnesium alloys in engine, piston, and cylinders especially in automotive sector and also such characteristics as hardness, wear resistance, and machinability. It is known that wear resistance is closely related with tensile properties of the material. Wear can be defined as resistance of metal against friction in its most basic sense. Today, the most commonly used Mg-Al (magnesium-aluminium) alloys are AZ91, AM20, AM60, AS21, AS41, AJ62 etc. The most significant properties of these alloys are their well castability and improvable tensile properties.

This study investigates the effect of Si (Silicon) and Mn (Manganese) on wear resistance and machinability, and also the effects on hardness, wear resistance, strength, and machinability depending on microstructure of AS91 and AM90 containing 1% Si and 0.5% Mn.

II. EXPERIMENTAL PROCEDURE

The magnesium alloy used AS91(containing 9%Al, 1%Si) and AM90 (containing 9% Al, 0.5% Mn) in the experimental study were prepared by melting pure magnesium (Mg) and Aluminium (Al), Al-Si and Al-Mn master alloys in a graphite crucible under Argon gas (Ar) atmosphere at 750°C. Mg, Al, and Zn bullions (with a minimum purity of 99.90%) used in the casting and aluminium silicon (Al-Si 50%) and aluminium manganese (Al-Mn 10%) master alloys bullions were supplied from Bilginoglu Co. AS91 and AM90 magnesium alloys used in this experimental study were obtained by cast into a cast iron mould (preheated to 270°C) under protective SF₆ gas. Detailed information on the production methods of the magnesium alloys can be found in the work of Unal [6]. The produced magnesium alloys samples were 22 mm in diameter and 200 mm in length. The chemical compositions of the alloys were determined by a Spectrolab M8 Optical Emission Spectrometry (OES). After the casting process characterization of the alloys were made by microscopic examinations and tensile tests. Alloy compositions are listed in Table I.

| TABLE I: CHEMICAL COMPOSITION OF THE STUDIED AS91 AND AM90 ALLOYS |
|-----------------------------|---------|-------|-------|-------|-------|-------|
| Alloys | Al% | Mn% | Zn% | Si% | Fe% | Mg% |
| AS91 | 9.3 | 0.1 | 0.2 | 1.2 | 0.02 | Rest |
| AM90 | 9.41 | 0.5 | 0.26 | 0.1 | 0.02 | Rest |

Microstructural surveys were conducted on the metallographic samples by optical microscopy (LV150 Nikon Eclipse). The samples prepared 12 mm in diameter and 15 mm in length were machined, ground with grit emery papers (200, 400 600, 800 1000, and 1200 grits, respectively), and then polished with 6μm, 3μm and 1μm diamond paste using pure water. Lastly, the samples were etched in a solution of...
100ml ethanol, 5ml Acetic acid, 6g picric acid and 10ml water for use in microstructural evaluations. X-ray diffraction (XRD) analyses (Panalytical-Empyrean) were carried out under Cu Kα radiation with an incidence beam angle of 2°. The tensile tests (ASTM E 8 M-99 standards) were performed at a crosshead speed of 0.8 mm/min⁻¹ and at room temperature (Shimadzu Autograph AGS-J 10 kN Universal Tester). The hardness values of the samples were determined by the Vickers hardness test (HV) with a load of 10N by using microhardness tester (Shimadzu HVM-2). At least ten hardness measurements were carried out on each sample.

Wear tests of experimental samples were carried out on pin-on disk test device (Fig.1) At the end of wear experiment, sizes of marks left on sample surfaces were measured and thus wear resistances of samples were estimated. Wear tests were performed on a reciprocating wear tester (Tribotester TM, Clichy) under a load of 4 N. Al₂O₃ balls having a 6mm diameter rubbed on the surfaces of the samples with a sliding speed of 5mm/s. The stroke of the Al₂O₃ balls was 5mm for a total sliding distance of 25m. Wear test samples were 15mm in diameter and 10mm in length. The coefficient of friction and frictional force were continuously recorded throughout the wear tests. Contact surfaces of the samples were examined using a surface profilometer (Dektak TM 6 M).

Cutting forces were implemented to evaluate the usage of two experimental methodologies. The feed rate (f) and depth of cut (DoC) were held constant to maintain the cross-sectional area of the chips in millimetres per revolution (mm/rev). The feed (f; mm min⁻¹) was held constant for various revolutions. The machining parameters and conditions of the experimental studies are given in Table II. The cast magnesium alloy samples were subjected to a pre-cleaning operation (i.e. diameter reduced from 22 to 20mm) before the experiments.

**TABLE II**

<table>
<thead>
<tr>
<th>Parameters and Conditions</th>
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<tbody>
<tr>
<td>Operations</td>
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<tr>
<td>Feedrate (f, mm/rev)</td>
<td>: 0.10 (Constantly)</td>
</tr>
<tr>
<td>Depth of Cut (DoC, mm)</td>
<td>: 1.0</td>
</tr>
<tr>
<td>Cutting Speed (Vc, m/min)</td>
<td>: 56, 112, 168</td>
</tr>
<tr>
<td>Cutting Conditions &amp; Lubricant-Coolant</td>
<td>: Orthogonal and Dry Cutting,</td>
</tr>
<tr>
<td>Workpiece Materials</td>
<td>: AS91 and AM90</td>
</tr>
<tr>
<td>Cutting Tool Properties</td>
<td>α, γ, λ, ε, κ, τε</td>
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<td></td>
<td>7°, 5°, 80°, 50°, 0.8</td>
</tr>
</tbody>
</table>

**III. EXPERIMENTAL RESULTS AND DISCUSSION**

A. Microstructure and Mechanical Properties

Microstructure photographs and XRD patterns of AS91 and AM90 magnesium alloys used in the study are given in Fig.3 and Fig.4, respectively. Microstructure of magnesium alloys analysed in the study was generally observed to be made up of α-Mg matrix and intermetallic phases. It was observed that network formation of Mg₁₇Al₁₂ intermetallic phase in AS91 Mg alloys tended to surround α-Mg grains throughout the matrix[7]. The intermetallic phase could easily be distinguished from the matrix under the optical light microscopy (Fig.3a).

In AS91 alloy, Mg₃Si intermetallic phase was present along with Mg₁₇Al₁₂ intermetallic phase [8]. Previous studies reported the presence of Mg₁₇Al₁₂ intermetallic phase in AZ91 alloy [9,10]. The formation of Mg₁₇Al₁₂ phase was repeatedly reported due to changes of the solidification behaviours of the melt caused by Zn addition [9,10]. In AS91 magnesium alloy, the constitution of the matrix is α-Mg phase, Mg₁₇Al₁₂, and Mg₃Si phases as shown in Fig.3. The formation of Mg₃Si phases in AS91 alloy appeared as Chinese script form in accord with the published literature [5,8-13]. In AM90 magnesium alloy, the constitution of the matrix is α-Mg phase and Al₆Mn₅ intermetallic phases as shown in Fig.3.

![Fig.1 Schematic view of the reciprocating wear tester utilized in this study.](image1)

![Fig.2 Schematic representation of experimental set-up with strain](image2)
B. Mechanical Properties

Hardness and wear values of the analysed alloys are given in Table III. When checked the mean hardness values of alloys, these were estimated to be 61.45 HV 10 in AS91 alloy and 88.5 HV 10 in AM90 alloy. The fact that AM90 demonstrated a higher hardness property resulted from the Al₅Mn₅ phase found in the microstructure.

Based on the data obtained from wear tests, presence of Al₅Mn₅ intermetallic phase in AM90 alloy microstructure provided the demonstration of a higher wear resistance at a rate of 22% compared to AS91 alloy. According to this, it was observed that the Al₅Mn₅ intermetallic phase that occurred thanks to the effect/presence of Mn in AM90 alloy increased wear resistance compared to (Mg₅Si,Mg₁₇Al₁₂) intermetallic phase formed due to the effect/presence of Si in AS91 alloy. A significant difference was not found between the friction coefficients of these two alloys. The reason for AM90 alloy to demonstrate a higher hardness and wear resistance compared to AS91 alloy was due to Al₅Mn₅ intermetallic phase found in the microstructure. When analysed the correlation between wear resistance and hardness in the experimental study, wear resistance was observed to increase depending on hardness (Table III). From this point of view, Al₅Mn₅ intermetallic phase found in AM90 alloy was observed to have an impact on hardness and wear properties. Experimental test results obtained from AS91 and AM90 series magnesium alloys are given in Table III.

Table III shows the dependence of the ultimate tensile strength (UTS), yield strength (YS) and elongation (EL) of the alloys studied on their Si and Mn content. The results obtained for UTS, YS and EL values could entirely be attributed to the presence of intermetallic phases (Mg₅Si,Mg₁₇Al₁₂,Mg₂Si and Al₅Mn₅) occurred in the structure. The various morphologies of the intermetallics indicate that particles were formed under various conditions [6,9-19]. Deviations from the reported results [12,16,19] are caused probably because of the production conditions such as casting temperature, solidification condition and impurity of the alloy.

C. Machining Properties

In the turning processes of AS91 and AM90 experiment samples used in the experimental study, data obtained as a result of applications conducted by keeping chip sections fixed are given in Fig.5. The highest cutting force in AM90 alloy was obtained as 55.7N at a cutting speed of Vc:168m/min, and as 49.8N in AS91 alloy; the lowest cutting force value was 43.12N in AS91 and 48.8N in AM90 at a cutting speed of 56m/min. It was observed at three different cutting speed selected in the experiment that cutting forces occurred during machining AM90 alloy was higher compared to cutting forces occurred during machining AS91 alloy. An increase was observed in cutting forces (with chip section fixed) due to a rise in cutting speed in machining AS91 and AM90 alloys (Fig.5). When compared the cutting forces, the highest cutting force value was obtained from AM90 alloy (Fig.5). From this point of view, it may be noted that the increase in cutting forces depending on cutting speed could occur due to dislocation build-up with chips in cutting edge.
Values of surface roughness that occur by machining AS91 and AM90 magnesium alloys are given in Fig.6. Both alloys were observed to have an increase in surface roughness as the cutting speed rises. It was observed that the surface roughness values obtained from AS91 alloy were higher compared to surface roughness values from AM90 alloy. It may be noted that intermetallic phases that occurred due to Si effect/presence (Mg$_2$Si, Mg$_{17}$Al$_{12}$) in the alloy had an impact on the formation of surface roughness values.

![Fig.6 Relationship between surface roughness (Ra) and cutting speeds of AS91 and AM90 series magnesium alloys](image)

Wears occurring due to machining AS91 and AM90 alloys on the surface of cutting edge surface are observed in Fig.7. When analysed cutting edge surfaces used in the experiment, it was established that Flank Build-up (FBU) occurred due to dry friction [13-16] between the work piece and cutting tool surface during the machining of AS91 and AM90 alloys and that cutting edges were worn. The said wear was found to be deeper in the cutting edge from AM90 alloy; and when analysed the cutting tool surface with which AS91 alloy was machined, chips were observed to advance along chip angle on a vaster surface (Fig.7c). Intermetallic phases (Mg$_2$Si, Mg$_{17}$Al$_{12}$ and Al$_3$Mn$_5$) that occurred/found in alloy were effective in the increase of the cutting forces. From this point of view, it was observed that Al$_3$Mn$_5$ intermetallic phase formed due the effect/presence of Mn in AM90 alloy had a harder structure compared to Mg$_2$Si, Mg$_{17}$Al$_{12}$ intermetallic phase formed due to the effect/presence of Si in AS91 and that this wore the cutting tool much more [17-19].

Flank Build-up (FBU) increase in the cutting surface between the cutting edge and sample surface due to intermetallic phases also causes a rise in cutting forces (Fig. 5) Flank Build-up (FBU) formation increases with friction and temperature rise occurring on the cutting tool surface due to an increase in cutting speed [14], and this may be noted to raise cutting forces (Fig.5)

![Fig.7 SEM image of cutting tool tip used for machining of magnesium alloys](image)

Images of chips obtained from machining AS91 and AM90 magnesium alloys are given in Fig.8. When analysed the chip images, it was observed that while chips formed from AM90 alloy were smaller in length and more plaited, chips from AS91 alloy were longer and helical [13,17]. When compared chips from AS91 with chips from AM90, it was found that chip lengths reduced and had more brittle breaks, and that chips were in the form of sawtooth. It may be noted that chips from AM90 alloy were smaller in length and occurred as a result of brittle breaks due to the effect of Al$_3$Mn$_5$ intermetallic phase, and in AS91 alloy, chips were longer and formed as a result of ductile breaks due to the effect of Mg$_2$Si and Mg$_{17}$Al$_{12}$ intermetallic phase (Fig.7). In both alloys, chip formations may be noted to occur due to intermetallic phases thanks to Si and Mn effect/presence (Mg$_2$Si, Mg$_{17}$Al$_{12}$ and Al$_3$Mn$_5$) found in the alloy [13]. It was observed that chips obtained from AM90 alloy were harder and fragile compared to AS91.

![Fig.8 Chip Formation of Magnesium Alloys ($V_c$:168 m/min, DoC:1mm, f:0.10 mm/rev).](image)

IV. CONCLUSIONS

The below results were obtained from this experimental study:

- Si and Mn found in the AS91 and AM90 alloys that were investigated in this study were effective on the hardness, wear resistance, and machinability of alloy in addition to having an impact on formation and type of intermetallic phases formed in the microstructure.
- It was found that intermetallic phases (Mg$_{17}$Al$_{12}$, Mg$_2$Si and Al$_3$Mn$_5$) of AS91 and AM90 magnesium alloys had an impact on cutting forces and machinability.
- AS91 alloy had lower hardness and wear resistance compared to AM90 alloy. AM90 alloy had higher machinability. While it was observed that chips formed by machining AM90 alloy were smaller in length, chips from AS91 alloy were longer. It was established that intermetallic phases were effective in the formation of chips and cutting force.
- Intermetallic phases were found to be effective on surface roughness. Higher surface roughness were obtained from AS91 magnesium alloy compared to AM90.
- Hardness and wear resistance of AS91 alloy was lower compared to AM90 alloy.
- Wear resistance and hardness (at Al$_3$Mn$_5$ intermetallic phase) of AM90 alloy was higher compared to AS91.
alloy (in which Mg\(_{17}\)Al\(_{12}\) and Mg\(_2\)Si intermetallic phase occurred).

- Intermetallic phases occurred from AS91 and AM90 magnesium alloys were observed to have an effect on machinability.
- Si and Mn were observed to have an effect on the formation of intermetallic phases in AS91 and AM90 magnesium alloys.

REFERENCES

Investigation of Metallurgical and Mechanical Properties of Weld Region of API 5L X80 Steel Joints by Submerged Arc Welding Method

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Abstract- In this study, API 5L X80 steel which are used in natural gas and petroleum pipeline were welded by submerged arc welding method (SAW). The micro-macrostructure and mechanical properties (tensile and hardness tests) of welded samples were investigated. In the mechanical tests, it was observed with the tensile tests that the ruptures were occurred from the base material. Besides, when the hardness tests were examined, the highest hardness values were determined in the weld metal. In the microstructure investigations, it was observed that acicular ferrite phase formed and fine grain structure was obtained in the weld metal. According to all results obtained from tensile-hardness tests and microstructure analyses, the welding process exhibited expected local properties as mechanical.

Keywords- API 5L X80, Submerged Arc Welding, Pipeline, Microstructure, Weld Region.

I. INTRODUCTION

Oil and natural gas are of great importance in the lives of people and in international relations as the most important energy resources [1]. Having such economic and strategic importance, oil and natural gas should be extracted from their sources and transported to the areas where they will be used. The transportation process occurs at high pressure and carried out through large diameter steel pipes [2]. Pipeline transportation is commonly used for transporting the products such as gas, oil, water or steam. Potential occurrence of natural events that might cause plastic deformation (landslide, dent, etc.) brings the importance of pipeline design and material selection to the forefront. Pipeline materials and connection systems must have the mechanical properties that can resist the harmful external effects [3]-[10].

Most of today's pipelines are manufactured in accordance with the API (American Petroleum Institute) standards. API 5L X80 steel is one of the high strength and low alloy (HSLA) steels used in natural gas and oil transmission and distribution lines [11]-[14]. It is among the fine-grained steels manufactured through controlled thermomechanical rolling [15]-[17]. X80 steel is commonly used in pipeline transportation due to good mechanical properties, ease of fabrication and low-cost [2], [18].

The pipes used in pipelines are usually welded by submerged arc welding with a spiral or longitudinal seam. Submerged arc welding is an automatic welding method and the performance and success of the welding process totally depends on the preference of the welding parameters. In this study, X80 steel materials manufactured in accordance with the API 5L specification were welded by submerged arc welding. The samples of the welded joints were subject to micro-macrostructural examinations as well as tensile and hardness testing. The study examined the effect of the welding process on the microstructure and mechanical properties.

II. MATERIAL AND METHOD

In the experimental phase of the study, 19.45 mm API 5L X80 steel pipes were used. Table 1 shows the chemical composition and mechanical properties of the material. Table 2 and 3 show the chemical composition of the welding wire and flux used in the welded joints.

<table>
<thead>
<tr>
<th>API 5L X80</th>
<th>C max</th>
<th>Si max</th>
<th>Mn max</th>
<th>P max</th>
<th>S max</th>
<th>Al max</th>
<th>Mo max</th>
<th>Ni max</th>
<th>Nb max</th>
<th>Yield Strength MPa (min)</th>
<th>Tensile Strength MPa (min)</th>
<th>Elongation (min)</th>
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<tr>
<td></td>
<td>0.08</td>
<td>0.26</td>
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<td>0.0005</td>
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<td>0.22</td>
<td>0.070</td>
<td>555</td>
<td>625</td>
<td>20</td>
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</table>
Welding was performed by employing a total of 4 runs (2 runs on the inside and outside). Fig. 1a and 1b show the geometry of welding groove and a list of weld runs. The welding process was carried out at Emek Pipe Company, by automatic spiral submerged arc welding. 4 different welding heads were used in the submerged arc welding unit. The weld runs no. 1.1 and 2.1 were performed using direct current (DC+), while the ones no. 1.2 and 2.2 were performed using alternating current (AC). Table 4 shows the welding parameters used in the process. Before the welding process, the materials were preheated at 80 °C and the temperature between the runs was kept at a maximum of 200 °C.

To determine the mechanical properties of the welded joints, 5 samples were taken from the joints in accordance with ASTM E8 to be subject to tensile test. Tensile tests were performed using the Instron testing machine with 600 kN capacity. Micrographs and macrographs of the joints were obtained from the microstructure samples. The hardness distribution of the welded joints was determined as macro hardness using Vickers (HV10) hardness test. Tensile and hardness tests were carried out in the laboratories of Emek Pipe Company. Micro-macrostructural examinations were performed in the laboratories of Gazi University Faculty of Technology Metallurgical and Materials Engineering Department.

The samples were ground and polished in accordance with the metallographic methods for the micro-macrostructural examinations and macro hardness measurements. The samples were then etched using 3% HNO₃ (Nital). Optical microscope was used for the microstructural examinations of the samples.

### III. RESULTS AND DISCUSSION

Fig. 2 shows the image of the macrograph of the samples taken from the welded joint. The macrograph shows no weld defects (undercut, crack, porosity etc.). The base metal, heat-affected zone (HAZ) and weld metal were clearly separated. Engagement of the weld runs were clearly seen on the inside and outside. The macrograph also shows that grains of the weld metal grew in the opposite direction to heat flow (towards the weld center), the penetration is good and the materials were welded perfectly.

---

### Table 2. Chemical composition of the S2Mo welding wire used in the tests.

<table>
<thead>
<tr>
<th>S2Mo</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>Mo</th>
<th>Cu</th>
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<tbody>
<tr>
<td>%</td>
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<td>0.96</td>
<td>0.10</td>
<td>0.009</td>
<td>0.007</td>
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<td>0.02</td>
<td>0.47</td>
<td>0.03</td>
<td>0.003</td>
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</table>

### Table 3. Chemical composition of the P223FX flux used in the tests

<table>
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<th>SiO₂</th>
<th>MnO</th>
<th>MgO</th>
<th>CaF₂</th>
<th>Al₂O₃</th>
<th>CaO</th>
<th>TiO₂</th>
<th>K₂O</th>
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<tr>
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<td>4</td>
<td>21</td>
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<td>20</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3 Max.</td>
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### Table 4. Welding parameters used in the tests

<table>
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<th>Current Type</th>
<th>Current Violence (A)</th>
<th>Arc Voltage (V)</th>
<th>Welding Speed (mm/min)</th>
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<td>4.0</td>
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<td>1125</td>
<td>30</td>
<td>1400</td>
</tr>
<tr>
<td>1.2</td>
<td>4.0</td>
<td>AC</td>
<td>675</td>
<td>32</td>
<td>1400</td>
</tr>
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<td>2.1</td>
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<tr>
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<td>4.0</td>
<td>AC</td>
<td>605</td>
<td>35</td>
<td>1400</td>
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</tbody>
</table>
Fig. 2 Macrograph of the X80 steel welded by submerged arc welding

Fig. 3 shows the micrographs of the welded joint. The base metal, HAZ and weld metal were shown in a single micrograph in Fig. 3. Fig. 3b-d shows the microstructures of the base metal, HAZ and weld metal, respectively.

Fig. 3a shows that the base metal has an equiaxed grain structure, while the HAZ has a grain structure getting coarser towards the joint line, and the weld metal has fine and rather needle-like grains. The phase with a white needle-like shape observed on the weld metal can be said to be acicular ferrite [17]. The formation of acicular ferrite which increased the toughness and strength of the weld metal could be said to occur due to the slow cooling rate that resulted from the preheating process (at 80 °C) [18].

Fig. 3 Micrograph of the a) Base metal (A) – HAZ (B) – Weld metal (C),

b) Micrograph of the base metal, c) Micrograph of the HAZ, d) Micrograph of the weld metal.
Table 5. Results of the tensile test.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Yield Strength (MPa)</th>
<th>Maximum Tensile Strength (MPa)</th>
<th>% Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base material X80</td>
<td>632</td>
<td>685</td>
<td>21</td>
</tr>
<tr>
<td>Weld Sample</td>
<td>638</td>
<td>696</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 5 shows the results of the tensile test. The findings show that the welded joints and the base metal have almost the same strength and percent elongation values. This indicates that the ruptures during the tensile test actually occurred on the base metal (Fig. 4). This could be interpreted as that the weld metal exhibited better strength than the base metal under mechanical loads. The reasons could be the lack of weld defects on the joints and the acicular ferrite formation which increased the toughness and strength of the weld metal [19-23].

Hardness measurements were performed at the points shown schematically in Fig. 5. Hardness was measured horizontally at 15 different points in order to determine the hardness of different microstructures (base metal, HAZ, weld metal) at the end of the welding process. Fig. 6 shows the results of the hardness test.
The results of the hardness test show that the highest hardness values were measured at the weld metal, while the lowest values were measured at the base metal (Fig. 5). The highest hardness values observed in the weld metal are thought to be caused by fusion-solidification thermal cycling, additional wire-weld powders and the formation of acicular ferrite.

IV. CONCLUSION

The findings of this study can be summarized as follows:

- In this study, API 5L X80 steel materials were welded by submerged arc welding, forming a “X groove”.
- Macrographs show that grains of the weld metal grew in the opposite direction to heat flow (towards the weld center), the penetration is good and the materials were welded perfectly.
- The ruptures observed during the tensile test were found to be occurred on the base metal.
- The weld metal was found to have high hardness. The lowest hardness values were measured at the base material.

ACKNOWLEDGEMENTS

The authors would like to thank the Gazi University Scientific Research Projects Coordination Department under the Grant No. 07/2016-05 and Emek Pipe Company for the supports.

REFERENCES


Characterisation of NiTi - Ti Powders
Fabricated by Mechanical Alloying Technique

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Abstract—In this study, pure Ti powders and Ni-rich NiTi shape memory alloy powders were prepared using the method of mechanical alloying and the effects of the addition of pure Ti powders were investigated. For this purpose, different Ti powder (10µm) ratios (respectively 2%, 4%, 6%) were mixed for mechanical alloying with Ni-rich prealloyed NiTi (30 µm) powders. 1:10 powder/ball ratio was used for mechanical alloying experiments. The samples were characterized by X-ray diffractometry (XRD), element distribution spectrometer (EDS), scanning electron microscopy (SEM) techniques. As a result of experiments, mechanical alloying technique is effective the Ti addition in NiTi alloy system.

Keywords—Prealloyed NiTi Powders, Shape Memory Alloys, Powder Metallurgy

I. INTRODUCTION

NiTi shape memory alloys, also known as Nitinol, have gained technical importance equally in biomedical and aerospace industries due to their excellent mechanical and shape memory properties.

NiTi shape memory alloys (SMA) obtain Ni and Ti alloys, also known Nitinol. This alloys having inimitable shape memory effect, good biocompatibility, excellent wear corrosion resistance effects, damping effect, have been using in many industrial and medical service application areas[1-3].

In general, NiTi SMA produce via casting technology. But using this technique, couldn’t obtain significant fracture resistance, super elasticity and ductility [4-5]. During production process and environmental conditions increase hydrogen amount which give rise to negative effects on mechanical properties. Better production technique is very important in this area [6-9]. Therefore, NiTi SMA could be fabricated by powder metallurgy (PM) technique recently. The best known and mostly used powder production techniques are gas atomization, pulverisation, hot isostatic pressing, sparcplasma and mechanical alloying [10-18]. Mechanical alloying technique was used in this area with change Ni and Ti content for NiTi alloy systems and the new alloy systems were synthesized [19-26].

In this study, pure Ti alloy (respectively 2, 4 and 6 %) was milled with prealloyed NiTi powders (55% wt.) by mechanical alloying technique. Scanning electron microscopy (SEM), element dispersion spectrum (EDS) and X-Ray analyses were applied on milled NiTi + Ti alloys system for determine to structure and properties.

II. EXPERIMENTAL RESULTS AND DISCUSSION

In general, NiTi alloys produce via conventional mass production technique. But this type of powders produced as the commercial and experimental couldn’t find. For this purpose, NiTi powders used in experimental studies were obtained by NANOVAL (NANOVAL GmbH&Co.KG Kienhorststraße 61-65 D-13403 Berlin) firm as prealloyed. Used prealloyed NiTi powders were produced by gas atomization technique. Figure 1.a shows pure surface quality and spherical powder morphology of prealloyed NiTi powders. Fig 1-b shows the irregular shaped powder structure of pure Ti powders.

Figure 1. SEM images; a) 30 µm sized prealloyed NiTipowders, b) 5 µm sized pure Ti powders
The average particle size distributions of prealloyed NiTi powders and pure Ti powders were respectively measured as 30 µm and 20 µm (Table 1).

<table>
<thead>
<tr>
<th>Powders</th>
<th>Average Size Distribution(µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiTi</td>
<td>30</td>
</tr>
<tr>
<td>Ti</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 1. The average particle size distribution of the powders

Ni content as the weight and the atomic percent of prealloyed NiTi powders respectively have 54.9 %wt. % ratio, as shown in Table 2.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Ti</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt %</td>
<td>45.1</td>
<td>54.9</td>
</tr>
</tbody>
</table>

Table 2. Weight and atomic Ti – Ni % of prealloyed NiTi powders

Figure 2 shows general EDS analyses of prealloyed NiTi powders (30 µm) used in experimental studies. In general only Ni and Ti elements could be confirmed. Different alloy elements were analyzed. However, the presence of only Ni and Ti elements in the alloy were identified. The particle morphology in all PM methods is now among the primary considerations. In this case, the spherical, flat and homogeneous particles are preferable in order to gain the appropriate parameters in the press ability and production stage of powders. This situation could be achieved with gas atomization and carbonyl methods [27]. Hence, the preference of gas atomization method to fabricate used powders shows the suitability of production parameter.

Figure 2. General EDS analysis of prealloyed NiTi powders

SEM image and EDS analyses of the pure Ti powders added prealloyed NiTi powders in mechanical alloying process are shown in Fig 3. It could be seen from Fig. 3-d (EDS analysis) that likely to be C and O elements in the structure were not determined depending on the production technology. This result shows the conformity of production parameter of NiTi powders.

Figure 3. SEM and EDS images of pure Ti powders
NiTi + Ti powders after 60 minutes milling by mechanical alloying technique are shown in Figure 4. When SEM images (Fig 4) of the pure Ti powders (respectively; 2, 4 and 6 % ratio) added prealloyed NiTi were investigated, the changes in the microstructure (Figure 4.a – b – c) with increasing of Ti content in alloying system were determined. However, the high hardness value of NiTi alloy and the lower hardness of the alloy element from NiTi alloy revealed the Ti powders coating on NiTi powders surface with increasing Ti content.

Figure 4. SEM images of NiTi + Ti powders after 60 minutes milling; a) 2% Ti, b) 4% Ti and c) 6% Ti

Figure 5 shows the SEM images and EDS analysis after 60 minutes milling. NiTi –2%Ti powders. When SEM image (Figure 5) was investigated, it was determined that Ti powders began to coating on NiTi powders surface after 60 minutes milling. With increasing of the Ti content such as 4% (Figure 6), it was determined to be more apparent of structural differences. The increasing of Ti content in alloyed powders was supported the EDS analysis (Figure 6.b). Also free Ti powders could be seen in EDS analysis (Figure 6.c). With increasing of Ti content (6% ratio) in milled alloy, increasing Ti coating ratio on NiTi powders is shown in SEM image (Figure 7.a). EDS analysis support to increasing Ti element ratios in NiTi powders (Figure 7. b and c).

Figure 5. NiTi + 2%Ti powders after 60 minutes milling; a) SEM image, b) EDS analysis of 1. point, c) EDS analysis of 2. point
Figure 6. NiTi + 4%Ti powders after 60 minutes milling; a) SEM image, b) EDS analysis of 1. point, c) EDS analysis of 2. point

Figure 7. NiTi + 6%Ti powders a) SEM image, b) EDS analysis of 1. point, c) EDS analysis of 2. Point

Figure 8 shows the XRD patterns of the mechanical alloyed powders after 60 minutes milling. In Figure 8, XRD analysis of the prealloyed NiTi powders was shown as the first sample. The highest intensity obtained after reflection by the NiTi powder belongs to NiTi peak with general 111 plane [28]. With mechanical alloying process in NiTi alloy system, amorphous structure could be achieved [19, 24]. In XRD results could be determined the structural differences on XRD intensity reflection ratio. The decrease of NiTi phase intensity was observed after 60 minutes milling. Also, with increasing the Ti content, the differentiation of peak intensities and the formation of different peaks were determined by XRD analysis (Figure 8. 2 – 3 – 4). In different experimental studies, XRD analysis of alloying elements added to NiTi alloy show to occur of differences [29].

Figure 8. XRD analysis of samples:
III. CONCLUSIONS

- Gas atomization technique used to fabricate prealloyed NiTi powders likely to occur oxide and carbon structures prevents and also directly effective in the formation of homogeneous, smooth and spherical powders.
- The structural differences of increasing of Ti content in NiTi alloy were determined with SEM images and also increased Ti ratio after EDS analysis were identified.
- The formation of amorphous structure, the differentiation of peak intensity and width were determined by XRD analysis depending on increased of Ti content after 60 minutes milling. Increasing with the covered ratio of Ti contents on NiTi powders was identified by mechanical alloying processing. This situation would be very effective for sintering period.

REFERENCES


Hydrophilicity Procedure of Agava Americana L. Fibers with Ecologic Methods

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Abstract—Agava Americana L. plant is known as century plant in Turkey belongs to Amaryllidaceae family. Commonly, the plant is cultivated in West Mediterranean Region and lingo-cellulosic fibers are obtained from the plant. Enzymes are defined as bio-catalysers consisted of the metabolic products of living organism. Trametes versicolor and Coriolus versicolor produce laccase enzymes. In this study, the fibers obtained from Agava Americana L. plant was treated with laccase enzyme at different concentrations (0.5, 1, 1.5, 2 and 2.5 %) in order to remove oils, waxes and other contaminations according to conventional and ultrasonic methods. After the enzymatic treatment, whiteness index, hydrophility and mechanical properties of samples were analysed in terms of concentration and treatment methods.

Keywords—Agava Americana L. fibers, laccase enzyme, ultrasonic method.

I. INTRODUCTION

In Turkey, textile industry, which is a leading sector of imports and exports, employs for 3 million people. However, textile industry in Turkey is going to different problems by the reason of making cheap production of Far East countries. For this reason, as a solution, use of innovative production methods and raw materials should be considered. In Turkey, cotton is the most produced fiber plants as well as linen and hemp are produced. In order to compete Far East countries, adaptation of different fiber plants should be carried out in Turkey. In this context, Agava Americana L. plants have fibrous structure and the plants are usually thrived in semi-arid region such as Mexico, Australia and Africa [1].

Agava Americana L. plant is known as century plant in Turkey belongs to Amaryllidaceae family [2]. Commonly, the plant which is an endemic plant in Turkey is cultivated in West Mediterranean Region and lingo-cellulosic fibers are obtained from the plant. Agava Americana L. plants and fibers are given in Fig. 1.

Fig. 1. Agava Americana L. plants and fibers.

Agava Americana L. plants are characterized with fleshy, hard-surface and lanceolate leaves. The length of leaves is 1 ranging from 1.5 m [3]. The leaves consist of numerous fibers which are high resisting and lingo-cellulosic structure. The fibers are obtained from leaves with mechanically, chemically or retting in seawater [3].

Agave Americana L. fibers are usually used in paper industry [4]–[6], technical textiles especially automotive industry because of having high mechanical properties [7]–[9]. Furthermore, the fibers can absorb metal ions such as Cd (II) and Pb (II) in aqueous solution [10], [11]. Agave Americana L. fibers are indicated that the fibers can be used as bioenergy...
source due to sustainable properties. In textile industry, in order to use Agave Americana L. fibers, oils, waxes and lignin should be removed from the fiber structure and the process can be carried out with enzymes, alkali, acetylation or chemicals [12], [13]. In textile industry, enzymatic hydrophilicity is an alternative method to conventional hydrophilicity methods. Studies have been showed that cellulases, pectinases, proteases, xylanases and lipases are the most common enzymes used in textile industry [14].

In this study, Agava Americana L. fibers were treated with laccase enzyme at different concentrations (0.5, 1.0, 1.5, 2.0, 2.5 and 3% concentration at 55 °C and pH 5.5 for 1 hour via conventional and ultrasonic methods. After the enzymatic treatment, whiteness index, hydrophility and mechanical properties of samples were analysed in terms of concentration and treatment methods.

II. MATERIALS AND METHODS

A. Materials

In this study, Agava Americana L. fibers were used. Agava Americana fibers were obtained from Agava Americana L. plant with carding process. The process of fibers obtained was given in Fig. 2.

![Fig. 2. The process of fibers obtained (a. Agave Americana L. plants , b. The cutaway view of plant leaves, c. The leaves waiting in water, f. The fibers obtained from water waiting process, g. Fiber separating machine).](image)

B. Methods

After the obtaining of fibers, fibers were treated with laccase enzyme (Denolite II S (Novozymes)) at 0.5, 1.0, 1.5, 2.0, 2.5 and 3% concentration at 55 °C and pH 5.5 for 1 hour via conventional and ultrasonic methods at the liquor ratio of 1:50. After the enzymatic treatment, whiteness index, tensile strength and hydrophilic properties of samples were analysed. The method of used on this study is given in Fig. 3.

![Fig. 3. The method of study.](image)

In order to analyse the hydrophilic properties of samples, 0.4 ml colored solution was dropped on the stretched position fibers. The duration of diffusion of the colorful drop to the surface with the length of 50 mm was measured.

Whiteness index of samples was determined by using Konica Minolta Spectrophotometer CM-3600d according to Stendsby Method and whiteness values were calculated using illuminant D65 and 10°standard observer values.

The tensile strength of samples was analysed with use Instron 4410 instrument, according to the ASTM D 3822 standard.

III. RESULTS AND DISCUSSION

A. Results of Hydrophilic Properties Measurements

The hydrophilic properties of samples were measured the duration of diffusion of colorful drop on the fibers surfaces. The results of hydrophilic properties measurement were given in Fig. 4.

![Fig. 4. The hydrophilic properties of samples.](image)
Fig. 4 shows the hydrophilic properties of samples. The results show that enzymatic pre-treatment raises hydrophilicity of samples. The increase of enzyme concentration causes to increase hyrophilicity of samples. The reason of these results was considered that the amount of reduced oils, waxes and other contaminants increases with increase of enzyme concentration.

B. Results of Whiteness Index Measurement
After the measurements of whiteness index of samples, the whiteness index properties of samples were calculated with Equation 1.

\[ W(CIE) = Y + 800(0.3138 - x) + 1700(0.3310 - y) \] (1)

The whiteness index results of samples were given in Fig. 5.

Fig. 5. The whiteness index results of samples.

Fig. 5 shows the whiteness index results of samples. According to the results, the enzymatic pre-treatment causes to increase whiteness index of samples. The reason of results was deemed that the enzymatic pre-treatment removes oils, waxes and other contaminants which are colorful components in the fibers. Furthermore, compared with conventional and ultrasonic method, ultrasonic method causes to increase whiteness index more than conventional method. Sonication energy removes oils, waxes and other contaminations more than heat energy. In addition, sonicatation energy cause to save of time and energy compared with conventional method.

C. Results of Tensile Strength Measurements
The tensile strength measurement results were given in Fig. 6.

Fig. 6. Tensile strength measurement of samples.

Fig. 6 shows the tensile strength measurements of samples. According to the Fig. 6, tensile strength of samples decreases with the enzymatic pre-treatment. In addition, the increase of enzyme concentration causes to increase in tensile strength of samples. Enzymatic pre-treatment removes some competent in the fibers. The tensile strength properties of samples were compared with regards to methods, conventional method causes more decrease. The duration of ultrasonic procedure is low than the duration of conventional procedure. Because of low duration procedure, amount of deformation is low.

IV. CONCLUSION
In this study, the usability of Agava Americana L. fibers in textile industry was investigated. In this context, Agava Americana L. fibers were obtained with fiber separating machine. After, the fibers were treated with enzymatic process with conventional and ultrasonic methods in order to reduce oils, waxes and other contaminates on the surfaces. Following enzymatic pre-treatment, hydrophilic, whiteness index and tensile strength properties of fibers were investigated. According to the results, enzymatic pre-treatment causes to increase hydrophobility and whiteness index. After the enzymatic pre-treatment, the tensile strength properties of fibers decrease. Compared with ultrasonic and conventional method, ultrasonic method causes to save of time energy. In addition, enzymatic pre-treatment is an ecological method due to being biologic materials. Furthermore, Agava Americana L. fibers can be used in textile industry after pre-treatment.

REFERENCES


Traditional Production and Wear Behavior of Composite Materials Reinforced Waste

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Bartın, Turkey

Abstract— Developments of material science constitutes the basis of technological development. Composite materials with superior properties are produced with combining materials whose physical and chemical properties are different. Thanks to the superior performance of metal composites meet the needs in aviation, aerospace industry, military applications and automotive industry, technology is developing rapidly. They are preferred because of their superior mechanical properties. In this study, we investigate the corrosion behavior of traditional and waste reinforced metal matrix composites. Al1014 (Al10O3) which is alloy, were used as a matrix material, the reinforcing members are SiC and MgO particles with a grain size of 10 μm - 25 μm and 50 μm micrometer, heater solid waste as the waste material (coal slag) were used. There will be an inferences with production of composite materials. SEM analysis and examining mechanical abrasion tests.

Keywords— Materials, Composite, Wear, Manufacturing, Alloy

I. INTRODUCTION

The importance of materials in many applications today come have The low cost of production and the intensive use of aluminum alloys in the industry has advantages over other materials. Together with the developments in technology as well as develop specific properties of materials, material development and the attractiveness of studies on the number of shows a day by day now. physical of traditional materials such as metals, due to the insufficient against the needs of today's technology of mechanical and thermal properties, is rapidly increasing interest in composite materials. In the production of composite materials, virtually all engineering materials are used. Composite materials are known to gather together the best features of the material is obtained by combining the macro level of at least two materials with different methods. Metal matrix composites, matrix and reinforcement to consist of two phases. Matrix materials can protect reinforcing members together while holding the reinforcing member transshipment reinforcing members against wear and corrosion. Prevent the spread of brittle cracks in the reinforcement member. The task of the reinforcement element to increase the strength of the matrix carrying the load. because of their low densities and production cost, aluminum and its alloys are at the forefront of metals and alloys commonly used in the industrial field. These alloys are mainly in the automotive sector, food showing a great improvement in recent years, are widely used in the aerospace industry. In this study we Al1014 as matrix material (Al10O3) alloy, the reinforcing member is 10 μm - with a grain size of 25μm and 50μm SiC and MgO particles are used. Heating disposed of as solid waste material (coal slag) were used. Particles, as the ratio of volume reinforcement to matrix material indicating the volume ratio of 5% - 10% and 15% values are selected. as composite manufacturing method, hot molding process is selected. In the crucible cast specially prepared by heating to 7800 C + particulate materials and test samples poured into the mold is prepared by mixing. In this way we aimed to investigate the corrosion behavior of the composite material is improved in the mechanical properties to some extent

II. COMPOSITE MATERIALS

A. Definition of Composite Materials

The most common meaning composite material; polycrystalline and multiple and diverse, is expressed as a collection of metal and non-metal compounds together [1]. Again according to yet another characterization; a composite material physically and / or chemically distinct, material containing suitably lined or dispersed phase [2]. A material must have certain characteristics to be considered composites. These characteristic;

- Different components together with chemically different from each other should be a combination of at least two materials.
- Materials forming the composite material should be combined in three dimensions.
- Composite formed by the combination of different materials must have better properties that can not have the features of the constituent components [1].

Classification of composite material is generally made according to the shape and structure of the structural matrix.
Composite materials are classified as follows according to the structural component. (I) Fiber Composites: reinforced with fibers composites, (II) Levasal Composites: derived by combining the flat plate composites (III) Particle Composites: reinforced with particulate composites (IV.) Impregnated (or a frame) Composites: Filling a second matrix material of a continuous skeleton, (V) laminated composites

Composites are divided into three according to the formed component layers of different matrix materials. (1) Ceramic matrix composites (II) Polymer matrix composites (III) metal matrix composites [1]

B. Metal Matrix Composites

The metal matrix composite are called that consisting of a variety of metal or metal alloy matrix composites. Metal matrix composites; generally continuous fiber as a reinforcement material, particles and whiskers are used [3]. Some of the advantages and disadvantages of metal matrix composite materials are

Advantages;

• High strength (abrasion, tensile and compressive) shows properties.
• Increased elasticity modulus (E)
• Increased yield and tensile strength
• Improved creep resistance
• Decreased coefficient of thermal expansion (CTE)
• Low density
• Increased elevated temperature strength
• Improved wear resistance

Disadvantages;

• Low fatigue strength.
• Low toughness and ductility.
• More complex and expensive production methods [6].

1) Materials Matrix Materials in MMK: Main function in matrix composite systems, to transmit the load applied to the composite reinforcement. matrix in the production of metal matrix composites. Aluminum alloy MMCs, which are also known as Aluminum Matrix Composites (or AMCs) or Discontinuously Reinforced Aluminum (DRA), have been the focus of the majority of research and development programs and indeed commercial applications. However, non-aluminum composites have also been produced using a wide range of matrix metals and alloys which also include copper alloys, iron and steel alloys, magnesium alloys, nickel-base superalloys, titanium alloys, and zinc alloys[3]. The popularity of aluminum as a matrix material is attributed mainly to: (i) its low cost ($1.5/kg) relative to other light structural metals, (ii) its current dominance of the aerospace structural application market, (iii) its introduction and acceptance in the automotive engine market, and (iv) its versatility in terms of properties and ease of fabrication. [4].

The matrices generally employed include 1000, 2000, 5000, 6000, 7000, and 8000 series aluminum alloys. Table 2.1 lists the typical compositions and applications of these alloys [5] As the material generally, Al, Mg, Cu, Zn, Ti, Pb, Fe, Ag, Sn and Si alloys are used [7]. Aluminum matrix in commercial applications and scientific research programs recently composites have been used widely [5]. Because the Al alloy used as a matrix material with good mechanical properties, low electrical conductivity, have low density and high corrosion resistance. This is cheaper than the other metals besides the features of ($1.5 / kg), easy to produce, its dominance in space applications in the automotive market and the other attractive features [6]. The metal matrix generally employed include 1000, 2000, 5000, 6000, 7000, and 8000 series aluminum alloys.

### TABLE I
SUMMARIZES THE CHEMICAL COMPOSITION OF THE ALLOY AND ITS APPLICATIONS

<table>
<thead>
<tr>
<th>Metal</th>
<th>Typical composition</th>
<th>Typical Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 Series unalloyed Al</td>
<td>&gt;99.00 wt.% Al</td>
<td>High ductility and conductivity, low strength: transmission lines, cooking foil</td>
</tr>
<tr>
<td>2000 Series major additive Cu</td>
<td>Al + 4 Cu + Mg, Si, Mn</td>
<td>Strong age hardening alloy: aircraft skins, spars, forgings, rivets.</td>
</tr>
<tr>
<td>3000 Series major additive Mn</td>
<td>Al + 1 Mn</td>
<td>Moderate strength, high ductility, excellent corrosion resistance: roofing sheet, cooking pans.</td>
</tr>
<tr>
<td>4000 Series major additive Si</td>
<td>Al + 11 Si</td>
<td>Casting alloy: Sand and die castings</td>
</tr>
<tr>
<td>5000 Series major additives Mg + Si</td>
<td>Al + 3 Mg 0.5 Mn</td>
<td>Strong, work hardening, weldable alloy: pressure vessels, ship superstructures, drink cans.</td>
</tr>
<tr>
<td>6000 Series major additives Mg + Si</td>
<td>Al + 0.5 Mg 0.5 Si</td>
<td>Moderate-strength age hardening alloy: anodized, extruded sections, e.g. window frames.</td>
</tr>
<tr>
<td>7000 Series major additives Zn + Mg</td>
<td>Al + 6 Zn + Mg, Cu, Mn</td>
<td>Strong age hardening alloy: aircraft forgings, spars, lightweight railroad carriage shells.</td>
</tr>
<tr>
<td>8000 Series Other elements, e.g. Li</td>
<td>e.g. Al + 3 Li</td>
<td>Low density and good strength: aircraft skins and spars</td>
</tr>
</tbody>
</table>
2xxx (alcunmg), 5xxx (AlMg), 6xxx (almeuc), the 7xxx (alznmgc) and 8xxx (Al-Li) aluminum alloys are used very widely in composite production [6,8]. In general, as the matrix alloy, with good strength values (2xxx) and (7xxx) alloys have found using one in commercial applications. (6xxx) alloys other than alloys, and provide convenience in production because it has a higher corrosion resistance is preferred as the matrix alloy. Aluminum-Lithium (8xxx) ensure a good ability to be welded of the alloy increased work on these alloys. Mg, and Al alloys containing alloying elements such as Li reinforcement phase as it forms a good bonding aluminum alloys containing these alloying elements are used as the matrix material [8].

2) Reinforcement material in MMK: Reinforcing materials used in the production of MMCs according to the structural shape is divided to as continuous and discontinuous [6-8]. Reinforcements are typically added to the strength of the composite matrix, may change the high temperature mechanical properties and hardness arttirnkrk density. The main task of reinforcing material is to carry the load applied to the composite. Reinforcement materials are divided into five according to their shapes. (i) continuous fibers, (ii) short fibers, (iii) whiskers, (iv) particles, (v) metallic wires [6,8]. The reinforcement materials are divided into four groups according to their chemical structure: (i) Oxides, (ii) Carbides, (iii) nitride (iv) Other (stainless steel, C, etc.) [9]. Fibers (f): continuous fibers rather high length / diameter ratio has. diameter of this type of reinforcement is about 100 μm. Final MMK exhibits high anisotropic property. The average price of a continuous fiber $ 1,000 / kg [6].

Whiskers are mono crystalline materials with high aspect ratios of 50 to 100. Their small size lends them to a variety of MMC production methods, although powder metallurgy (P/M) is the most popular. The typical cost of whisker reinforcements are $20-40/kg Whisker-reinforced MMCs are mainly used in the form of extrusions, forgings, and rolled sheet. The properties of the finished MMCs range from isotropic to slightly anisotropic, and costs range from moderate to high, according to the mechanical and physical properties. Particle average price of $ 10 / kg [6].

Table II

<table>
<thead>
<tr>
<th>Reinforcement</th>
<th>Particle Size(µm)</th>
<th>Reinforcement</th>
<th>Particle Size(µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alumina Particules</td>
<td>3-200</td>
<td>Magnesium</td>
<td>40</td>
</tr>
<tr>
<td>SiC Particules</td>
<td>6-120</td>
<td>Sand</td>
<td>75-120</td>
</tr>
<tr>
<td>SiC Whiskers</td>
<td>5-10</td>
<td>TiC Particules</td>
<td>46</td>
</tr>
<tr>
<td>Graphite Lameller</td>
<td>20-60</td>
<td>Boron Nitride Particules</td>
<td>46</td>
</tr>
<tr>
<td>Graphite Lameller</td>
<td>15-100</td>
<td>Silicon Nitride Particules</td>
<td>40</td>
</tr>
<tr>
<td>Mica</td>
<td>40-180</td>
<td>Iron Skin</td>
<td>75-120</td>
</tr>
<tr>
<td>Silica</td>
<td>5-53</td>
<td>Zirconium</td>
<td>5-80</td>
</tr>
<tr>
<td>Zirconium</td>
<td>40</td>
<td>Titanium</td>
<td>5-80</td>
</tr>
<tr>
<td>Glass Particules</td>
<td>100-150</td>
<td>Lead</td>
<td>-</td>
</tr>
<tr>
<td>Glass Bead</td>
<td>100</td>
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</tbody>
</table>

Particle in Al matrix composites as a supplement, typically, SiC and Al2O3 particles are used. Some important properties of these particles is shown table [10].

Table III

<table>
<thead>
<tr>
<th>Particle</th>
<th>Elastic Modulus</th>
<th>Density</th>
<th>Coefficient Thermal expansion</th>
<th>Specific Heat</th>
<th>Thermal Conductivity</th>
<th>Poisson ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiC</td>
<td>420-450</td>
<td>3.2</td>
<td>4.3x10^-7</td>
<td>840</td>
<td>10-40 at 1100°C</td>
<td>0.17</td>
</tr>
<tr>
<td>Al2O3</td>
<td>380-450</td>
<td>3.96</td>
<td>7.0x10^-7</td>
<td>1050</td>
<td>5-10 at 100°C</td>
<td>0.25</td>
</tr>
</tbody>
</table>

C. Production Method of MMC Material

Many methods are used in the production of metal matrix composites. While the classification of the composite manufacturing method is possible in many different ways, using the matrix form; liquid phase, the solid phase and two (solid + liquid) phase can be in the form of a classification method [9].

1) Liquid Phase Production Methods: Liquid phase production methods are methods that composite production occurs in the liquid phase. In liquid phase processes, the ceramic particles in the matrix by using different and appropriate techniques are added. These methods include methods by mixing ceramic particles in liquid metal, compression molding, pressure and non-pressure infiltration, xD method [9].

2) Liquid Metal-Ceramic Particles Mixing Methods: Addition of the liquid matrix alloy and
particles of a reinforcing material in the form of methods are used to obtain the uniformly dispersed in the liquid matrix reinforcement. Techniques used for mixing liquid particles to metal [9].

- using an injection gun; Injecting ceramic particles in the liquid with an inert gas.
- Into liquid metal (composed of matrix alloy and particles shaped reinforcing material) Adding and mixing of small pellets.
- liquid obtained by mixing ceramic particles with the help of vortex molten metal is mechanically joined to the metal.
- The addition of the liquid metal inside of the mold with molten metal filling the ceramic particles.
- ceramic particles to be pushed into the liquid using reciprocates rods.
- Central-liquid particles with few effects to be distributed into the metal.
- continuous vibrating liquid metal with ultrasound, to reinforce the liquid metal into the ceramic particles [9,12].

Particle-reinforced composite material production conditions in the foundry most efficient and economical method to use, vortex method. In this method, consists a mechanical stirrer (propeller) and consists of a furnace. The matrix alloy is melted in a crucible. When the desired vortex is obtained, a vortex of the particulate reinforcing material is mechanically mixed with a certain given propeller in the center and the liquid feed rate to be deployed in a homogeneous manner in the metal. It is necessary for the uniform control of the following parameters; (I) the liquid metal composition and temperature, (ii) mixer depth, speed and pitch, (iii) stirring time, (iv) the time elapsed between the end of mixing and casting, (v) characteristics of the molding material [13]. The biggest drawback of mixing; It is the porosity of the products. Porosity was a lot of work on minimizing be. Stirring of the control was made in a vacuum atmosphere and the crucible surface is said to reduce the amount of porosity of the blown gas, such as argon-nitrogen. Porosity rate depends on heat treatment applied to the particles prior to mixing speeds and production. The moisture layer on the particles to cause the liquid to prevent the porosity of the metal particles is necessary to maintain the heat-treated before being added to the matrix. Another important disadvantage of vortex method; (I) gluing together of the ceramic particles during mechanical mixing, (ii) collapsing particles of the crucible bottom, and (iii) segregation of the reinforcing material in the matrix, (iv) large interfacial reaction, (v) cleavage of the ceramic particles [9]

3) Compression Cast: In this method the liquid alloy, comprising reinforcement preforms are impregnated with the pressure provided by the hydraulic press, as shown in Figure 2. mold to avoid solidification of the liquid alloy, and the preform is subjected to preheating staples. Reinforcement particles comprising the preform is heated to a temperature exceeding the melting temperature of the matrix alloy. Preform metal exceeds the melting temperature of the preheat temperature of the fluid penetration to be completed, but under high pressure in the liquid leaking from the gap between the punch and the mold. Important parameters affecting the quality of compression molding composites; (I) the mold preheat temperature, (ii) the applied pressure, (iii) is the density of the preform or bed tucked [13,14].

On the other hand penetration rate spaces between and particles are the factors that affect the quality of the composite. In fiber reinforced composites of the staple of the damage to the preform moving very fast and fibers causes poor infiltration. In this method, Acritical pressure requires for allowing fullfluid flow top reform [11].

4) Pressureless Infiltration: Liquid metal, including reinforcement preform spontaneously developed by this patented method is infiltrating Lanxiu. In this method, the pressing, the preforms produced by techniques such as injection molding allows the infiltration of pressure during Al-Mg alloy in a nitrogen atmosphere. Including pressureless infiltration method with 55 to 60 vol% Al2O3 or SiC composite materials can be produced [9,10]. Alloy-ceramic system is heated to 800-1000 °C.

\[
\text{reaction that infiltration of development,} \quad N_2 + 3 \text{ Mg} \rightarrow \text{ Mg}_3\text{N}_2 \quad (2.1)
\]

\[
\text{reaction during infiltration;} \quad \text{Mg}_3\text{N}_2 + 2 \text{ Al} \rightarrow 2\text{AlN} + 3\text{Mg} \quad (2.2)
\]

During heating the infiltration temperature evaporates magnesium and magnesium supplements covering surface reacts with nitrogen to form nitrides. Magnesium supplements nitrite pressure or vacuum application of the alloy is a compound that allows the excess infiltration. System is schematically shown in Figure 2.2. immersed
into the liquid within the heated preform is provided of the same method it is also a variant of self infiltration [12]. aluminum nitride composite material produced in the microstructure, increases the hardness of the composite and reduces the thermal expansion coefficient [7].

Fig. 2 Pressureless infiltration schematic representation of the process

Done at high temperature makes the reaction occurring in the production of composite preform interfaces. The oxidation of the reaction of the preform interface, causing a matrix material containing oxide and unreacted. And complex-shaped composites can be produced with high density is the most important advantages of the pressureless infiltration technique [7].

5) Pressure Infiltration: In many cases it is weak Islatabilirig external pressure is needed to infiltrate into the liquid metal preform. widely used in the production of metal matrix composite pressure infiltration method. This method consists of porous metal gas pressure infiltration of fluid into the preform [9]. Preforms, particles, whiskers or a compact version of the supplements in the form of fibers or been agglomerate. Other casting methods for producing composite reinforcement can be admixed with up to 30%, the composite can be produced containing high proportions of up to 70% reinforcing element in this method [6]. The advantages of the pressure infiltration method include; (I) it is quicker and simpler than other methods, (ii) has a low production cost, and (iii) can be obtained composite piece having the shape of the desired end product [4,6,14]. The disadvantages of this method; (Ii) non-homogeneous microstructure, (ii) the porosity due to very close together reinforcements structure, (iii) coarse grain size, (iv) adverse interfacial reactions, (vi) failure of the reinforcement [6,9]. Pressure infiltration method is described in Section 3.1

6) XD Method: Martin Marietta XD method developed by the company, is a patented production method. XD methods, chemical compounds are added to form the reinforcing member for the production of the composite material into the matrix material in liquid form reinforcement particles of the present production method, the chemical compounds are obtained by reacting in the liquid matrix alloy. These supplements obtained most of the particles are produced TiB_2 and TiC according to the following reaction [10].

\[
2B + Ti + Al \rightarrow TiB_2 + Al \quad (2.3)
\]

\[
C + Ti + Al \rightarrow Al TiC \quad (2.4)
\]

Matrix particles are formed by the reaction, in a single crystalline, it has clean and unoxidized interface. Although it varies between 0.25-1.5 micron particle size by altering production parameters such as the reaction temperature is between 0.2-10 um particles of varying size can be obtained [10].

7) Solid Phase Production Methods: Powder Metallurgy, Ceramic particles due to the difficulty in the production of composite developed first wetted by the liquid alloy is a powder metallurgy method [9]. In this method, whisker or particulate reinforcement material in the form of metal or alloy powders are mixed with sieved. The mixture is then molded by cold or hot pressing. cold pressing after the molding, is sintered in order to increase the particle strength and matrix interface. After sintering, to provide an intermediate product having a density of 75-85%. This intermediate product is beaten after the degassing process is rolled or extruded [8-10]. Metal powders are usually atomized powder in 20-40 um size [7,10]. Because supplements significantly affect the distribution in the matrix of the powder mix is an important step in powder metallurgy method. Metal or alloy powd the oxide layer can be formed on the particles, matrix-reinforcement interface reduces the strength and leads to cavities. To avoid the removal of water molecules from the gas space it must be carried out under vacuum or hot and cold pressing [10]. After sintering the final product is about 20: 1 and higher rates are obtained by extrusion. High extrusion rate; provide a link between the development of dust, to distribute the oxide film between the metal powder particles, and therefore particles to prevent agglomeration of particles is required to ensure homogeneous distribution. The advantages of powder metallurgy method include: (i) the matrix as most metals and metal alloys can be used, (ii) supplemented with can be minimized the reaction between the matrix, a variety of reinforcement can be used, (iii) high reinforcement enables one to composite production volume ratio [10 ]. Powder metallurgy method also has some disadvantages. These are: (i) highly reactive, processing of explosive powder, (ii) to have a complex production processes, and (iii) is not limited to producing shapes the initial product obtained [10]

8) High Speed Method: Successfully used methods for bringing together the metal powder containing fine
ceramic particle distribution, "high speed-high energy methods are known as. In this method, the reinforcing metal-ceramic mixture is obtained by periodically applying high energy in a short time. As well as high mechanical energy to electrical energy sources are expressed can be used successfully in the production of metal matrix composites. High energy and high speed, provides rapid heating of the conductive powder in the mold. short-term operation at a given temperature, phase transformations and provides control of the grain coarsening. successfully used in the production of high energy-high-speed method of Al-SiC composites [15].

9) Diffusion Linking: In this method is carried out using supplements or block between Flemma single metal or alloy foils. the bonding surfaces are made of metal or reinforced in metallurgical polishing level. After polishing SiC and Al, ultrasonically cleaned in acetone or ethanol. Surface cleaning is very important in connecting the diffusion, working to provide high cleanliness required in various chemicals. below the melting temperature hold at 50 MPa pressure for 2 hours, afterwards cooling in the furnace operation is carried out [12].

10) Dual Phase Production Methods: Dual phase production methods, the matrix alloy dual phase (solid + liquid) at temperatures that are contained comprises the reinforcing particles added to the matrix. Dual phase production methods; osprey method and semi-solid mixing method [9,12].

11) Osprey Method: In this method, under an atmosphere of inert gas to make up a composite material atomized liquid matrix alloy is converted into molten metal while the spray flow. Ceramic particles introduced into the spray and metal matrix composite material consisting of the mixture to be deposited on a substrate [9]. The size of the metallic particle is approximately 20 to 40 μm. reinforced metal matrix ratio is limited and this rate is around 30%. The interaction of the liquid matrix and ceramic reinforcement phase is limited. limited reaction occurs at the interface and in this case the better mechanical properties of the composite effects [10]. It is a homogeneous dispersion in the matrix of reinforcing particles. Is porosity of the produced composite and has a higher cost compared to other methods, this method has disadvantages. [8]

12) Semi-solid mixing: The method, also called the Compocasting and Rheocasting made by mixing semi-solid with a solid between the solidus liquidus technical supplement is added. The temperature of the alloy is removed liquidus temperature of 30-50 °C on violent way is allowed to cool by mixing the semi-solid range. This ongoing activity, breaking dendrite is solidified into fine spherical particles and prevents the rise in semi-fluid viscosity. Supplements added while stirring is performed. Relatively low viscosity pourable mixture with the form of direct index. In this case the method "rheocasting" takes its name. It is removed on a continuous stirring liquidus temperature "compocasting" is called [12].

D. Uses of Aluminum Matrix Composites

MMC materials tend to be more expensive than the matrix alloy is typically used in applications where high costs outweigh the benefits of strength and elastic modulus. With advancing technology in recent years it has increased the expected properties of the materials used and, therefore, has expanded the usage of MMCs. Lately need space and aviation, as well as resistant to high temperatures in the automotive industry, high-strength, high wear resistance and the use of MMCs can protect high temperature these properties and production has greatly increased [5].

NASA and the US Department of Defense in the 1960s and 1970s, the continuous carbon and boron fibers with development and production, research and development activities on a continuous boron fiber-reinforced composite Al-B began to play [4].

The most important increase in the use of MMCs in 1982 was realized with the use of short fiber reinforced aluminum composite Al₂O₃ Toyota's piston rings [16]. To reduce operating and fuel costs in technological applications, thereby reducing the weight and strength of the material / It is important to increase the intensity ratio [5].

Al major use of the metal matrix composite aerospace / military applications and the automotive industry. In recent years, also in the electronics industry in the manufacture of superconducting cables and sporting goods MMCs are used.

1) Aerospace / Military Applications: Characteristic of aerospace applications, is the production of small quantities. Those obtained from the embodiments save weight, allowing improvement in fuel economy. Spacecraft in the benefits of weight saving $ 2000 / kg and more in civil aircraft 100-1000 $ / kg. Continuous fiber reinforced metal matrix composites that require high strength and temperature resistance, but the cost of aviation is important in aerospace and military applications with more applications. Continuous fiber reinforced MMCs are Al missiles systems, compressor rotors, are used in warheads system.

When the fan and compressor blades, in addition to material creep properties of lightness, high modulus of elasticity and strength are important, boron fiber reinforced aluminum alloy to carry the body of a spaceship matrix composites were produced. Fiber reinforced composites of different composition is used in jet engine fan blades. Due to the good high temperature properties of aluminum alloys reinforced with continuous graphite fiber has attracted attention in various military applications [4,5]. Al graphite fiber reinforced metal matrix composite materials in rocket and helicopter parts, Al₂O₃ fiber reinforced Al metal matrix composite materials are used in the construction
of helicopter gears [17]. Short fiber or whisker-reinforced composites are usually found in areas of the conveyor system and telescope. Particle reinforced composites in the wing panels, etc. In satellite solar reflective it is used. The cause of particulate reinforced composites industry compared to other supplements in uzayhavacılık more preferred, is isotropic properties and is providing more save weight [5].

2) Automotive Applications: In the automotive industry, it is desirable that the weight gain and high wear characteristics, the use of metal matrix composites lately has become quite prevalent [4,5,16]. The advantages of using metal matrix composites for automobile parts include: (i) weight saving especially engine parts, (ii) high attrition resistance, (iii) improved material properties, (iv) low coefficient of thermal expansion [16]. fuel savings with the reduction of the weight of the car is increasing. In cars and large vehicles, saving weight and $ 0.5-2 / kg may be [5]. Instead of cars in the steel shaft 20% Al2O3 fiber reinforced Al with the use of metal matrix composites, in addition to weight savings, the reduction of vibration and rotation speed of the shaft is provided critical grow [17]. Graphite Al2O3 particles reinforced Al engine block, cylinder liners made from metal matrix composites increased heat transfer, thermal expansion coefficient of the composite that minimize the dimensional tolerances between the liner and the piston is low and thus the motor efficiency is saving fuel increasing. Automobile Al SiCp the use of composite materials in the piston-weight gain, provided wear resistance and thus increase life of the piston [11].

III. EXPERIMENTAL STUDIES

AL 1014 as the matrix mateiral in the study (AL2O3) alloy, the reinforcing member is 10 microns with a grain size of 25 microns and 50 microns SiC and MgO particles arae used. Heating the solid waste in the waste materrial (coal slag) were used

Fig. 3 Heating solid waste (coal slag) view

Fig. 4 The view from the first ball mill

After the coal burned in the boiler slag remaining waste materials are collected kalorf ball mill is dimensioned.

Fig. 5 The view from the ball mill

Fig. 6 Ball view from the ground material from the mill

Fig. 7 See the screening of the material in the sieve
Ball mill grinding materials in various diameters (micro level) have been screened through the sieve classification. Samples were made available in various sizes.

Particles, as the ratio of volume reinforcement to matrix material indicating the volume ratio of 5% - 10% and 15% values are selected. As composite manufacturing method, hot molding process is selected.

Then we make steel molds used and dump samples successfully cast is made of composite materials.

Fig. 8 Mold view

+ 780ºC heated up in the pot casting specially prepared test specimens and particulate materials are poured into the mold is prepared by mixing.

Fig. 9 The sand mold casting

Process has made the first encounter various problems. Sand mold cavity in the prepared sample in the sample have experienced breakage to occur.

Fig. 10 The prepared sand mold samples from the fracture appearance

In this study, wear tests Bartin University continues to be supported by Scientific Research Project. Heating the solid waste in the production of composite materials (coal slag) by using a successful casting process took place.
REFERENCES

TO SELECT ALUMINUM ALLOYS FOR MANY APPLICATIONS WITH AN EXPERT SYSTEM

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Abstract-Aluminum, one of the five most widely used metal in metal based industries, has 8 different series and over 30 different alloys. Each alloy has different mechanical and chemical properties. It can meet the requirements of many applications with various needs thanks to this variety. However, the variety of choice also comes with the complexity of choice of the most suitable aluminum alloy. Hence, the choice of optimal aluminum alloy has become an area that requires special expertise.

In this study, an expert system that can select the most suitable aluminum alloy using the input of a user was developed. The expert system that is called Al_expert was built up an expert system shell program, Kappa PC. Kappa PC is preferred for some advantages that have inference engine tools and rule base, and programming with C++. The system uses multi-criteria weighted average method. Al_expert has a friendly user interface that is designed visual objects. More than 100 rules are written for Al_expert. The system asks a few simple questions to user about Al alloy. And, Al_expert can make a decision by using forward chaining method. Finally, Thus, Al_expert system can select an ideal Al alloy automatically.

As a result show that Al_expert makes easy to select ideal Al alloy for any application area without any expert. In this way, the system helps any user select the most suitable alloy and reduces faults and unnecessary choices.

Keywords - Aluminum Selection, Alloy, Expert System, Kappa PC, Data Mining, MCDM Methods

1. INTRODUCTION

Materials of Aluminum are widely in many industries on the world. Aluminum is not used in its pure form in manufacturing industry [1]. Hence, different alloys are produced with various chemical, physical or mechanical properties [2]. Aluminum has 8 different series and over 30 different alloys. Due to this variety, it is very difficult to choose the most suitable alloy that has many different properties. Choosing the most suitable aluminum has become an area of expertise.

Expert systems are basically computer algorithms that are used for decision making and problem solving [3]. Expert systems are built by knowledge engineers and experts over many years of experience. The expert systems use their own databases and rules to reach a intermediate decision. Each decision is then used as an input of another stage until the final decision is made.

Expert systems provide improvement in quality and reliability in manufacturing industry [4]. For this particular reason that various studies exist regarding the use of expert systems to help users choose correctly. The studies are explained below.

İpek et al. has developed an expert system to choose materials used in car parts in automobile industry [5]. The developed system chooses among a pre-defined number of metals, composites and polymer materials. Strength, weight, formability, corrosion durability and price are the main criteria of decision making process. Zanandi et al. proposes an expert system that chooses the most environmentally friendly, ecological and sustainable materials by their social, economic and environmental factors [6]. Another expert system proposed by Blundell and Gennway classifies materials according to their static load resistance, torque transmission, operation temperature and corrosion durability [7]. Kayir, et al. [8] were built up an expert system by using Leonardo shell program for selection optimal cutting tools and operation for drilling holes. Poyrazoglu, et al. [9] were implemented an expert program to choose right operation from non-traditional machining methods.

In this study, we address the problem of aluminum alloy selection as opposed to other studies. An expert system that was developed by using KAPPA-PC expert shell program, is used to determine the most suitable aluminum alloy using the most basic requirements as an input. The system is called Al-Expert. The system comprises of rule base, user interface,
inference module and help module. The most widely used 16 types of aluminum alloys are determined in Al-Expert. The most suitable aluminum alloy is selected by AI_Expert. The expert system uses multi-criteria decision making (MCDM) method [10] and the method allows the user to change the importance factor of any parameter. This allows the expert system to sort the alloys by scores calculated from user input and relative weights.

II. ALUMINUM ALLOY

Aluminum is the third most frequent element found in the nature. In spite of this fact, it can’t be used in its pure form. An advanced manufacturing process is required to make the aluminum usable. For this very reason aluminum is widely utilized in the late 1800s. Advances in industrial methods and the advances in material science motivated by two world wars emerged different alloys of aluminum. Aluminum alloys are basically categorized in 6 different series in Al_expert program. The basic properties of the alloys are as such:

<table>
<thead>
<tr>
<th>ALLOY SERIES</th>
<th>ALLOY ELEMENT</th>
<th>PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1XXX</td>
<td>Pure (&gt;99)</td>
<td>Excellent Thermal and Electrical conductivity, Excellent corrosion resistance and weldability, Low Strength</td>
</tr>
<tr>
<td>2XXX</td>
<td>Cu</td>
<td>High strength, good temperature strength, Low corrosion resistance, High machinability</td>
</tr>
<tr>
<td>3XXX</td>
<td>Mn</td>
<td>Medium strength, good formability, Good corrosion resistance</td>
</tr>
<tr>
<td>5XXX</td>
<td>Mg</td>
<td>Medium strength, good formability, Excellent marine corrosion resistance</td>
</tr>
<tr>
<td>6XXX</td>
<td>Mg+Si</td>
<td>Medium-High strength, good corrosion resistance, Easily extruded, good weldability</td>
</tr>
<tr>
<td>7XXX</td>
<td>Zn</td>
<td>Very high strength, poor corrosion resistance, Welding not applicable</td>
</tr>
</tbody>
</table>

Aluminum 7075, indispensable raw materials of aerospace industry, was developed during 1940s by Japanese. During 1960s, aluminum was utilized in manufacturing process of engine blocks in automobile industry. Aluminum is a widely recognized raw material in various industries such as pressure vessels, chemical industry, and ship industry. Aluminum owes this wide recognition to having many alloys that have very different mechanical, chemical and physical properties. Choosing the most suitable alloy among these alloys are very critical in quality and production time of the end-product.

Choosing among 16 different aluminum alloys based on 6 different aluminum series is a difficult task. The user is be able to choose the most suitable aluminum type using the proposed expert system.

III. OVERALL SYSTEM DEVELOPMENT

The flowchart below shows the structure of the developed expert system. The expert system consists of inference module, database, help module and user interface.

Fig 1. Al_Expert flow chart

A. Al_Expert Selection System and Database

The expert system analyzes the input using inference module. The evaluation of user input is based on the pre-defined inputs by experts, catalogs and literature surveys. All physical, chemical and mechanical properties of aluminum alloys are pre-defined in the developed expert system. To improve user-friendliness, some sections of the developed system includes symbolic statements instead of numerical counterparts. The current system includes 16 different aluminum alloys and 9 different parameters. The parameters are listed in Table 2

<table>
<thead>
<tr>
<th>TABLE II</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Al_Expert SELECTION SYSTEM PARAMETERS</strong></td>
</tr>
<tr>
<td><strong>Al-Expert Parameters</strong></td>
</tr>
<tr>
<td><strong>Physical Properties</strong></td>
</tr>
<tr>
<td>Aluminum Form</td>
</tr>
<tr>
<td>Heat treatment</td>
</tr>
<tr>
<td>Material</td>
</tr>
</tbody>
</table>
B. Al_Expert Selection Module

All properties of aluminum alloys are defined in a database. We built an expert system called “Inference Module” that chooses aluminum alloy using the input from the user. The decision tree of the expert system consists of three elements: objects, classes and slots.

Objects are part of the main program and are used to group basic events in the program. The developed aluminum alloy expert system consists of 4 objects (Fig. 2). These are Aluminiun, userinput, calculation and constant.

Classes are parameters of objects.

The figure below shows classes of objects that are connected to objects with dashed lines. For instance, there are different classes for 9 different properties of the material connected to the object that holds the input from the user.

Slots are the part that holds data belonging to a class.

The system comprises of functions and rules. The system has 21 function that define button events. In kappa-pc, rules are created with IF – THEN structures (Fig.3). The core algorithm of the developed expert system is rule based, and it simply follows rules to reach a result. The expression in “THEN” part gives the result, which is then used as an input to another condition to reach the desired solution.

The expert system algorithm is run until the desired slot value of a class of an object is calculated. Hierarchical structure between rules can be viewed by Fig. 4. In Al_expert rule base was designed by writing around 81 rules. Moreover, Al_expert system is capability of use forward chaining method to solve problems.

```
IF
    ( Calculation:H1000 > Calculation:H1050 ) And
    (Calculation:H1000 > Calculation:H2014 ) And
    (Calculation :H1000 > Calculation:H7075 ) And
    (( Userinput:Form == Rod ) And
      ( Userinput:Form == Sheet ) Or
      ( Userinput:Form == Bar ) Or
      ( Userinput:Form == Wire ) Or
    );
THEN
    SetValue( Aluminum:AluminumTypes, 1000 );
```

Fig 3. Al_Expert system sample rule structure

Aluminum alloy expert system is developed using multi-criteria decision making (MCDM) method [10]. The parameters of this method and the weights of the parameter are defined by user. The score of an alloy is calculated by first evaluating all inputs and multiplying each with their respective weights. The scores of alloys are evaluated using MCDM, and then sorted from highest to lowest to recommend the most suitable alloy to the user.
C. Help Module

Help module give some details and information to user about decision support system parameters. With the help of the module user will get the information about solution. In addition to this mechanical parameter calculation method is sharing with user in help module.

D. User Interface

A user interface was designed between Al_expert program and user. Many pages were created for the user interface. The user can learn about the program by using these pages. The user manual page is shown in Fig. 6.

The expert system is able to choose according to user's priorities as it scores user inputs by their importance level as weights. As of now, the system is capable of assessing 16 different most used alloys of 6 different aluminum series. As can be seen in figure 7, the system firstly assesses alloys depending on the material form. For instance, wire will only be chosen among 1050, 6061 and 6063 series. Hence, the user is offered to the right aluminum series and forms that are easily

IV. CONCLUSION

In this study, an expert system was developed for selection aluminum alloy. Thus, Al_Expert system can solve problems about selection right aluminum alloys unnecessary an expert. Al_expert is good stable program to detect an optimal aluminum alloy. Because, Al_expert decide based on 9 different parameters for aluminum alloys. This system can provide a lot of advantages to user. The planning time and costs can decrease for selection aluminum alloys in many industries.

If desired to improve system some different parameter can describe system database. Shearing strength, elongation percent and termal parameters are some of those. Existing system don't interest cost of alloy. According to user requirements cost parameter will be added. New module can developed for Al_expert which is identify new aluminum alloy to knowledge database of system about based on user input. One of the capability and expertise of Al_expert system is to become a useful assistant for user in aluminum and metal based area.
VI. REFERENCES


Mechanical and Thermo-Mechanical Buckling Analyses of Composite Cylindrical Shells

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Abstract— In this study, Mechanical and Thermo-Mechanical Buckling characteristics of thin-walled fiber reinforced composite cylindrical shells have been investigated. Glass/Epoxy and Carbon/Epoxy composite materials are used and mechanical and thermo-mechanical buckling loads are determined for these material types. The composite plies are laid up to form eight-ply laminates having [0|90]s, [15|75], [30|60] and [45|45]. Comparisons of effects of different fiber orientations on buckling loads with different temperatures are discussed. These analyses are performed using commercial finite element analysis program ANSYS. Effects of temperature, material types and aspect ratio (diameter / length) on mechanical and thermo-mechanical loads are analyzed.

Keywords— Composite, Mechanical buckling, Thermo-mechanical buckling, cylindrical shells.

I. INTRODUCTION

Composite materials are an important part of the material science and these materials are used in the design of many engineering structures. These structures are many times used in the form of cylindrical Shells. These structures are used in areas such as aerospace, automotive, civil engineering and marine. Since thickness of composite cylindrical shell structures are small compared to the other dimensions, design of these structures needs to be controlled to the buckling loads. The load-carrying capability of cylindrical shells without occurring buckling is important and has been considered and investigated by many researchers [1-7].


Shiau et al. [12] studied thermal buckling behavior of composite laminated plates by making the use of finite element method. Barton [13] presented an approximate closed-form solution to compute the thermal buckling response of a symmetric angle-ply laminates that are clamped in one edge and free along the other edge. Results are compared with Rayleigh-Ritz method solutions.

Engineering structures can expose high temperatures and mechanical loads. So designing these structures only with mechanical buckling cases is insufficient. In this study, Mechanical and Thermo-Mechanical Buckling characteristics of composite cylindrical shells have been investigated. Glass/Epoxy and Carbon/Epoxy composite materials are used during the study. Comparisons of buckling loads with different temperatures, different fiber angles, and with different aspect ratios (length/diameter) have been performed.

II. NUMERICAL STUDY

Equivalent buckling analysis is performed by using finite element analysis program ANSYS. Thermo-mechanical, and mechanical buckling loads are determined for composite cylindrical shells. Glass/Epoxy and Carbon/Epoxy composite materials are used during the study and their mechanical properties are given in Table 1.

Used fiber orientations are given in Table 2. As seen in this Table, 4 different orientation are used. 0, 15, 30, and 45 are stand for [0|90|0|90], [15|75|15|75], [30|60|30|60], and [45|45|45|45], respectively. In the study, both sides of the cylindrical shells are fixed and lateral (external) unit pressure is applied as shown in Fig. 1.

<table>
<thead>
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<th>Material Properties</th>
<th>Glass Epoxy</th>
<th>Carbon Epoxy</th>
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<td>$E_1$ (GPa)</td>
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<td>70e9</td>
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<tr>
<td>$E_2$ = $E_3$ (GPa)</td>
<td>11.72e9</td>
<td>70e9</td>
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<tr>
<td>$\nu_12$</td>
<td>0.25</td>
<td>0.28</td>
</tr>
<tr>
<td>$\nu_13$</td>
<td>0.25</td>
<td>0.28</td>
</tr>
<tr>
<td>$\nu_23$</td>
<td>0.25</td>
<td>0.28</td>
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TABLE 1. Material Properties cont.

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<th>G_{13} (GPa)</th>
<th>G_{23} (GPa)</th>
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TABLE 2. Fiber orientation

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<td>[15/-75/15/-75]_s</td>
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<td>45</td>
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Fig. 1. Boundary conditions and loading

III. ANALYSIS RESULTS

1) Mechanical Buckling

Mechanical buckling loads are determined for Glass/Epoxy and Carbon/Epoxy composite cylindrical shells with different fiber orientations. Diameter (D) of cylinder and thickness (t) are taken as 100 mm, and 2 mm, respectively.

External (lateral) unit pressure load is applied then critical buckling loads are determined. Fig. 3 shows that Both Glass/Epoxy and Carbon/Epoxy, 0° has minimum buckling load and 45° has maximum buckling load. When Glass/Epoxy and Carbon Epoxy are compared, it is seen that Carbon/Epoxy has higher buckling load as expected. Buckled shapes of the composite cylindrical shell is given in Fig. 2.

Fig. 2. Buckled shape of composite cylindrical shell

Fig. 3. Variation of buckling loads with fiber angle a) Glass/Epoxy, b) Carbon/Epoxy

Fig. 4a. shows the mechanical buckling loads for Glass/Epoxy with aspect ratios (length / diameter) (L/D) varying from 1 to 5. As can be seen from fig., Mechanical buckling load is decreased by changing L/D from 1 to 5 up to 40.1% for 30°, 25.2% for 15°, 9.2% for 0°, and 3.7% for 45°.
Fig. 4b. shows the mechanical buckling loads for Carbon/Epoxy with aspect ratios (length / diameter) (L/D) varying from 1 to 5. As can be seen from fig., Mechanical buckling load is decreased by changing L/D from 1 to 5 up to 54.3% for 30°, 25.1% for 15°, 1% for 0°, and 8.9% for 45°.

As can be seen from Fig. 5., Mechanical Buckling load is decreased by increasing temperature from 25 °C to 150 °C up to nearly 80% for both Glass/Epoxy and Carbon/Epoxy.

![Graph of buckling load vs L/D for Carbon/Epoxy](image)

![Graph of buckling load vs Temperature for Glass/Epoxy](image)

![Graph of buckling load vs Temperature for Carbon/Epoxy](image)

2) Thermo-Mechanical Buckling

Effects of temperature for the different materials are important and cause the decrease of performance of the materials during the operation conditions. Hence in this section, mechanical buckling loads are determined with varying temperature. The cylinder of length (L), diameter (D) and thickness (t) are taken as 250 mm, 100 mm, and 2 mm, respectively.

Fig. 6 shows the mechanical buckling loads for Glass/Epoxy with aspect ratios (length / diameter) (L/D) varying from 1 to 5 and temperature changes from 25 °C to 150 °C. At different L/D ratios, there is not huge difference at buckling load.
summarized as:

Mechanical buckling loads for Glass/Epoxy with aspect ratios (length/diameter) varying from 1 to 5 is decreased to 54.3% for 3°, 25.1% for 15°, 1% for 0°, and 8.9% for 45°.

Mechanical Buckling load is decreased by increasing temperature from 25 °C to 150 °C up to nearly 80% for both Glass/Epoxy and Carbon/Epoxy.

The mechanical buckling loads for Glass/Epoxy with aspect ratios (length / diameter) (L/D) varying from 1 to 5 and temperature changes from 25 °C to 150 °C. At different L/D ratios, there is not huge difference at buckling load.

IV. CONCLUSIONS

Thermo-mechanical and mechanical buckling characteristics of the composite cylindrical shells have been investigated in this study. Glass/Epoxy and Carbon/Epoxy are used as material types. Effects of temperature, material types, fiber orientations and aspect ratios on buckling load have been searched. From the present study, the conclusions can be summarized as:

- Both Glass/Epoxy and Carbon/Epoxy, 0° has minimum buckling load and 45° has maximum buckling load. When Glass/Epoxy and Carbon Epoxy are compared, it is seen that Carbon/Epoxy has higher buckling load.
- Mechanical buckling loads for Glass/Epoxy with aspect ratios (length / diameter) (L/D) varying from 1 to 5 is decreased to 40.1% for 30°, 25.2% for 15°, 9.2% for 0°, and 3.7% for 45°.
- Mechanical buckling loads for Carbon/Epoxy with aspect ratios (length / diameter) (L/D) varying from 1 to 5 is decreased to 54.3% for 30°, 25.1% for 15°, 1% for 0°, and 8.9% for 45°.
- Mechanical Buckling load is decreased by increasing temperature from 25 °C to 150 °C up to nearly 80% for both Glass/Epoxy and Carbon/Epoxy.
- The mechanical buckling loads for Glass/Epoxy with aspect ratios (length / diameter) (L/D) varying from 1 to 5 and temperature changes from 25 °C to 150 °C. At different L/D ratios, there is not huge difference at buckling load.

REFERENCES

Termo-Mechanical Vibration of Functionally Graded Nano Plates and Beams Based on Couple Stress Theory

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Abstract — This paper presents free vibration behavior of nano plates and beams made of functionally graded material subjected to thermal loading based on the modified couple stress theory. Material properties of the plates and the beams are dependent both the thickness direction and temperature. The material distribution is modelled in power-law in the thickness direction. The inclusion of an additional material parameter enables the new plate and beam model to capture the size effect. The new non-classical plate and beam model reduces to the classical plate and beam model when the length scale parameter is set to zero. In the solution of the problem, the Navier type solution is used for simply-supported boundary conditions. In the numerical results, the effects of the different material distributions, material length scale parameter, temperature rising on the fundamental frequencies of functionally graded nano plates and beams are investigated in both classical theory and modified couple stress theory in detail. Also, the effect of the temperature dependent physical properties is discussed for free vibration characteristics of nano FG structures.

Keywords — Nano Structures; Functionally Graded Material; Vibration; Couple Stress Theory

I. INTRODUCTION

With the increasing in technology, nano structures have found many applications. micro Carbon nanotubes and micro tubes are widely used in micro- and nano electromechanical systems (MEMS and NEMS) such as sensors (Zook et al. [1], Pei et al. [2]), actuators (Senturia [3], Rezazadeh et al. [4]). In the mechanical behavior of the nano structures, the classical mechanics is not capable of investigation of the size-dependent behaviors. Classical continuum mechanics does not contain the size effect, because of its scale-free character. So, nonclassical continuum theories such as higher order gradient theories and the couple stress theory are capable of explanation of the size dependent behaviors which occur in nano structures.

Functionally graded materials (FGMs) are a new generation of composites where the volume fraction of the FGM constituents vary gradually, giving a non-uniform microstructure with continuously graded macro properties such as elasticity modulus, density, heat conductivity, etc.. Typically, in a FGM, one face of a structural component is ceramic that can resist severe thermal loading and the other face is metal which has excellent structural strength. FGMs consisting of heat-resisting ceramic and fracture-resisting metal can improve the properties of thermal barrier systems because cracking and delamination, which are often observed in conventional layered composites, are reduced by proper smooth transition of material properties. Since the concept of FGMs has been introduced in 1980s, these new kinds of materials have been employed in many engineering application fields, such as aircrafts, space vehicles, defense industries, electronics and biomedical sectors, to eliminate stress concentrations, to relax residual stresses, and to enhance bonding strength. With the advance of the material science, micro–electro-mechanical systems are the new field in which FGMs have been utilized to achieve the desired performance. With the development of technology, FGMs are initialized to be used in micro/nano structural systems.

The nonlocal continuum theory initiated by Eringen [5] which has been widely used to mechanical behavior of nano-micro structures. The size effect plays an important role on the mechanical behavior of microstructures at the micrometer scale that the classic theory has failed to consider when the size reduces from macro to nano ((Toupin [6], Mindlin [7], Mindlin [8], Fleck and Hutchinson [9], Yang et al [10], Lam et al. [11]). Therefore, higher-order theories modified couple stress theory and modified strain gradient are used in the mechanical model of the nano-micro structures (Yang et al [10], Lam et al. [11]) proposed the modified couple stress theory (MCST) in which the strain energy has been shown to be a quadratic function of the strain tensor and the symmetric part of the curvature tensor, and only one length scale parameter is included. After this, the modified couple stress and the strain gradient elasticity theories have been widely applied to dynamic analysis of FG plates ([12-22]) and FG beams ([23-37]).

In this paper, the free vibration responses of FG nano simple supported beam and plate subjected to thermal loading are studied based on the MCST. Material properties of the plates and the beams are dependent both the thickness direction and temperature. The material distribution is modelled in power-law in the thickness direction. The considered problem is solved by using the Navier type solution for simply-supported boundary conditions. In the numerical study, the effects of the different material distributions, material length scale parameter, temperature...
rising on the fundamental frequencies of the functionally graded nano plates and beams are investigated in both classical theory (CT) and MCST. Also, the effect of the temperature dependent physical properties on the vibration behaviour of nano FG structures is investigated.

II. THEORY AND FORMULATIONS

The material properties are both temperature-dependent and position-dependent. The effective material properties of the functionally graded beam, \( P \), i.e., Young’s modulus \( E \), and mass density \( \rho \) vary continuously in the height direction \( (Y \) axis) and a function of temperature \( T \) (see Touloukian [38]) as follows;

\[
P(T) = P_{T}(P_{T}T^{-1} + 1 + P_{B}T + P_{T}T^{2} + P_{T}T^{3})
\]  

where \( P_{T} \) and \( P_{B} \) are the material properties of the top and the bottom surfaces of the micro beam. It is clear from Eq. (1) that when \( Y = -h/2, P = P_{B} \) (\( P_{B} \) is the material properties of the bottom) and when \( Y = h/2, P = P_{T} \) (\( P_{T} \) is the material properties of the top). Where \( n \) is the non-negative power-law exponent which dictates the material variation profile through the thickness of the micro structure.

Material properties of the FG beam are temperature-dependent and change in the thickness direction \((Y \) axis) according to a power-law form.

\[
P(Y, T) = (P_{T}(T) - P_{B}(T))\left(\frac{Y}{h}\right)^{n} + P_{B}(T)
\]  

where \( P_{T} \) and \( P_{B} \) are the material properties of the top and the bottom surfaces of the micro beam. It is clear from Eq. (1) that when \( Y = -h/2, P = P_{B} \) (\( P_{B} \) is the material properties of the bottom) and when \( Y = h/2, P = P_{T} \) (\( P_{T} \) is the material properties of the top). Where \( n \) is the non-negative power-law exponent which dictates the material variation profile through the thickness of the micro structure.

The beams considered in numerical examples are made of Zirconia and Aluminum Oxide. The bottom surface of the functionally graded beam is Zirconia and the top surface of the functionally graded beam is Aluminum Oxide. The coefficients of temperature \( T \) for Zirconia and Aluminum Oxide are listed in Reddy and Chin [39].

In the modified couple stress theory, the strain energy density for a linear elastic material which is a function of both strain tensor and curvature tensor is introduced for the modified couple stress theory Yang et al. [10];

\[
U_{i} = \int_{V} (\sigma : \varepsilon + m : \chi) \, dV
\]

where \( \sigma \) is the stress tensor, \( \varepsilon \) is the strain tensor, \( m \) is the deviatoric part of the couple stress tensor, \( \chi \) is the symmetric curvature tensor, defined by

\[
\sigma = \lambda \, \text{tr}(\varepsilon)I + 2\mu \varepsilon
\]

\[
\varepsilon = \frac{1}{2}[\nabla \mathbf{u} + (\nabla \mathbf{u})^{T}]
\]

\[
m = 2l^{2} \mu \chi
\]

\[
\chi = \frac{1}{2}[\nabla \theta + (\nabla \theta)^{T}]
\]

where \( \lambda \) and \( \mu \) are Lamé’s constants, \( l \) is a material length scale parameter which is regarded as a material property characterizing the effect of couple stress, \( \mathbf{u} \) is the displacement vector and \( \theta \) is the rotation vector, given by

\[
\theta = \frac{1}{2} \text{curl} \, \mathbf{u}
\]

The parameters \( \lambda \) and \( \mu \) in the constitutive equation are given by

\[
\lambda(Y) = -\frac{E(Y) \nu(Y)}{(1 + 2\nu(Y))(1 - \nu(Y))}, \quad \mu(Y) = \frac{E(Y)}{2(1 + \nu(Y))}
\]

where \( E \) is the modulus of elasticity and \( \nu \) is the Poisson ratio and their dependence on \( Y \) coordinate are given by Eq. (1).

2. Governing equations of FG nano beams

Based on Euler-Bernoulli beam theory, the strain of the beam and the curvature tensor \( \chi \) are expressed as

\[
\varepsilon_{xx} = \frac{\partial u_{0}(X, T)}{\partial X}, \quad Y = \frac{\partial^{2} v_{0}(X, T)}{\partial X^{2}}
\]

\[
\chi_{xx} = \frac{1}{2} \frac{\partial^{2} v_{0}(X, T)}{\partial X^{2}}
\]

where \( u_{0} \) and \( v_{0} \) components of the displacements. The constitutive relations is expressed as

\[
\sigma_{xx} = E(Y, T) \varepsilon_{xx}
\]

\[
m = 2l^{2} \mu(Y, T) \chi
\]

The elastic strain energy \((U)\) and the kinetic energy \((T)\) are expressed as

\[
U_{i} = \frac{1}{2} \int_{0}^{L} \left[ A_{11} \left(\frac{\partial u_{0}}{\partial X}\right)^{2} - 2B_{11} \left(\frac{\partial u_{0}}{\partial X}\right) \left(\frac{\partial^{2} v_{0}}{\partial X^{2}}\right) + A_{55} \left(\frac{\partial^{2} v_{0}}{\partial X^{2}}\right)^{2} \right] \, dX
\]

\[
T = \frac{1}{2} \int_{0}^{L} \left[ I_{1} \left(\frac{\partial u_{0}}{\partial X}\right)^{2} - 2I_{2} \left(\frac{\partial u_{0}}{\partial X}\right) \left(\frac{\partial^{2} v_{0}}{\partial X^{2}}\right) + I_{3} \left(\frac{\partial^{2} v_{0}}{\partial X^{2}}\right)^{2} \right] \, dX
\]

where

\[
(A_{11}, B_{11}, D_{11}) = \int_{A} E(Y, T)(1, Y, Y^{2}) \, dA,
\]

\[
A_{55} = \int_{A} \mu(Y, T) \, dA,
\]

\[
(A_{11}, B_{11}, D_{11}) = \int_{A} E(Y, T)\alpha(Y, T)(1, Y) \, dA
\]

\[
(I_{1}, I_{2}, I_{3}) = \int_{A} \rho(Y)(1, Y, Y^{2}) \, dA
\]

In deriving the governing equations of the FG nano beam, the Hamilton’s principle is used;

\[
\delta \int_{0}^{L} [T - U_{i}] \, dt = 0
\]
After using the Hamilton’s principle, the governing equations of the FG nano beam can be obtained as follows:

\[
\frac{\partial N}{\partial x} = I_3 \frac{\partial^3 u_0}{\partial x^2} - I_2 \frac{\partial^3 w}{\partial x^2} \tag{15a}
\]

\[
\frac{\partial^2 M}{\partial x^2} + \frac{\partial^2 P}{\partial x^2} - N_1 \frac{\partial^3 w}{\partial x^2} = I_3 \frac{\partial^2 u_0}{\partial x^2} + I_2 \frac{\partial^3 u_0}{\partial x^2} - I_3 \frac{\partial^3 w}{\partial x^2} \tag{15b}
\]

where \(N, M, P, \) and \(N_1\) are stress resultants, and expressed as follows:

\[
(N, M, P) = \int_A \left( \sigma_{x\gamma}, Y \sigma_{x\gamma}, m_{xy} \right) \, dA \tag{16a}
\]

\[
(N_T) = \int_{-0.5h}^{0.5h} (E(Y, T)) \, d\tau \tag{16b}
\]

In the solution of the governing equations, Navier method is used for free vibration of a simply-supported FG nano beam. In the Navier solution, the displacement fields are expressed as follows:

\[
u(x, t) = \sum_{n=1}^{N} A_n e^{i\beta_n t} \cos(kx) \tag{17a}
\]

\[
w(x, t) = \sum_{n=1}^{N} B_n e^{i\beta_n t} \sin(kx) \tag{17b}
\]

where \(\beta_n\) is the natural frequency, \((A_n, B_n)\) are the unknown constants, \(k = \pi n / L\) and \(i = \sqrt{-1}\). Substituting eq. (17) into eq. (15), and then using matrix procedure the governing equations of the problem can be solved.

### 2.2 Governing equations of FG nano plates

According to the Kirchhoff-Love plate theory, the strain-displacement relation and the curvature tensor \(\chi\) are expressed as

\[
\varepsilon_{x_1} = \frac{\partial u_0}{\partial x_2} - X_3 \frac{\partial^2 w}{\partial x_2^2} \tag{18a}
\]

\[
\varepsilon_{x_2} = \frac{\partial u_0}{\partial x_1} - X_3 \frac{\partial^2 w}{\partial x_1^2} \tag{18b}
\]

\[
\varepsilon_{x_1x_2} = \frac{1}{2} \left( \frac{\partial^2 w}{\partial x_1^2} + \frac{\partial^2 w}{\partial x_2^2} - 2X_3 \frac{\partial^2 w}{\partial x_1 \partial x_2} \right) \tag{18c}
\]

\[
\chi_{x_1x_1} = \frac{\partial^2 w}{\partial x_2^2} \tag{18d}
\]

\[
\chi_{x_1x_2} = -2X_3 \frac{\partial^2 w}{\partial x_1 \partial x_2} \tag{18e}
\]

\[
\chi_{x_2x_2} = -2X_3 \frac{\partial^2 w}{\partial x_1 \partial x_2} \tag{18f}
\]

\[
\chi_{x_1x_2} = \frac{\partial^2 w}{\partial x_1^2} \tag{18g}
\]

\[
\chi_{x_2x_2} = \frac{\partial^2 w}{\partial x_2^2} \tag{18h}
\]

The constitutive equations of the nano plate are as follows:

\[
\sigma_{ij} = \frac{E(Y, T)}{1 - \nu^2} \left[ \varepsilon_{x_1} \delta_{ij} + (1 - \nu) \varepsilon_{x_2} \right] \tag{19a}
\]

\[
m_{ij} = 2 \mu(Y, T)^2 \chi_{x_i} \tag{19b}
\]

The elastic strain energy \((U_i)\) and the kinetic energy \((T)\) of the nano FG plate are expressed as follows:

\[
U_i = \frac{1}{2} \int_A \left( \sigma_{ij} \varepsilon_{ij} + m_{ij} \chi_{ij} \right) \, dA \, dX \tag{20a}
\]

\[
T = \frac{1}{2} \int_0^L \int_A \rho(Y, T) \left[ \frac{\partial u_0}{\partial t} \right]^2 + \left( \frac{\partial w}{\partial t} \right)^2 + \left( \frac{\partial w}{\partial x} \right)^2 \right] \, dA \, dX \tag{20b}
\]

The Hamilton’s principle of the problem:

\[
\delta \int_0^L [T - U_i] \, dt = 0 \tag{21}
\]

After using the Hamilton’s principle, the governing equations of the FG nano plate can be obtained;

In the solution of the governing equations, Navier method is used for free vibration of a simply-supported FG plate. In the Navier solution, the displacement fields are expressed as follows:

\[
u(x, y, t) = \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} A_{mn} \cos(kx) \sin(py) e^{i\beta_n t} \tag{22a}
\]

\[
w(x, y, t) = \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} B_{mn} \sin(kx) \cos(py) e^{i\beta_n t} \tag{22b}
\]

\[
w(x, y, t) = \sum_{m=1}^{\infty} \sum_{n=1}^{\infty} C_{mn} \sin(kx) \sin(py) e^{i\beta_n t} \tag{22c}
\]

where \(\beta_n\) is the natural frequency, \((A_{mn}, B_{mn}, C_{mn})\) are the unknown constants, \(k = m\pi / a, \, p = n\pi / b\) and \(i = \sqrt{-1}\).}

### III. NUMERICAL RESULTS

In the numerical study, the effects of the different material distributions and temperature rising on the fundamental frequencies of the functionally graded nano plates and beams are investigated in both classical theory (CT) and MCST in figures. The structural elements considered in numerical examples are made of Zirconia and Aluminum Oxide. The bottom surface of the functionally graded beam is Zirconia and the top surface of the functionally graded beam is Aluminum Oxide. The material properties and coefficients of temperature \(T\) for Zirconia and Aluminum Oxide are listed in Reddy and Chin [39]. The reader can found the material properties in Reddy and Chin [39]. In numerical examples, the initial temperature (installation temperature) of the beam is assumed to be \(T_{i}=300\) K.

#### 3.1 The results of FG nano beam

In figure 1, the effect of material distribution (the power-law exponent) and the aspect ratio \((L/h)\) on the dimensionless fundamental frequency \((\beta = \omega h^2 \frac{L}{\sqrt{E A^3}})\) of the FG nano beam for \(AT=300\) K, the width of the beam is \(b=1\) mm for CT and MCST.

It is seen from Fig.1 that increase in the aspect ratio leads to a decline on effects of size effect and difference between the results of MCST and CT. Also, as seen from Fig.1 that with increase in the power-law exponent \((n)\), the dimensionless fundamental frequency decreases. This is as expected, due to the fact that an increase in the ratio of the \(n\) can decrease the
elasticity modulus and bending rigidity of the FG nano beam according to equation (2). As a result, the strength of the material increases.

Figure 2 shows that the effect of temperature rising (ΔT) and the aspect ratio (L/h) on the dimensionless fundamental frequency of the FG nano beam for n=2, the width of the beam is h=1 nm, the height of the beam is h=1 nm, the length of the beam is L=200 nm for CT and MCST.

It is seen from Fig. 2 that increase in the temperature, the fundamental frequency decreases because of the temperature dependent physical properties. Also it is seen from Fig. 2 that the results of the CT are always larger than those of the MCST.

3.2 The results of FG nano plate

In figure 3, the effect of material distribution (the power-law exponent) and the dimensionless material length scale parameter (l/t) on the dimensionless fundamental frequency (β = ωL / √(E_A h^3)) of the FG nano plate for ΔT=500 K for the height of the beam h=1 nm for the widths of the plate a=b=30h for CT and MCST.

It is seen from fig.3, with increase in the power-law exponent (n) the dimensionless fundamental frequency decreases like the results of the FG nano beam. Another result from Fig. 3 that increase in the ratio of l/t the difference between of CT and MCST increase significantly. It shows that the material parameter and material distribution has a very important role on the vibration responses of the nano structures.

Figure 4 shows that the effect of temperature rising (ΔT) and the aspect ratio (l/t) on the dimensionless fundamental frequency of the FG nano plate for n=2 for the height of the beam h=1 nm for the widths of the plate a=b=30h for MCST.

As seen from Fig.4 that increase in the temperature, the fundamental frequency decreases as expected. In the temperature-dependent physical properties, with the temperature increase, the intermolecular distances of the material increase and intermolecular forces decrease. As a result, the strength of the material decreases. Hence, the structure becomes more flexible with rising in temperature.

IV. CONCLUSIONS

In this study, free vibration characters of FG nano simple supported beam and plate investigated with temperature-dependent physical properties in both MCST and CT. The
Navier type method is used for the solution of the problem. In the numerical results, the effects of the different material distributions, material length scale parameter, temperature rising on the fundamental frequencies of the functionally graded nano plates and beams are investigated in both classical CT and MCST. It is observed from the numerical results that the material parameter and material distribution play important role on the vibration responses of the nano structures. Also, the thermal effect leads to change significantly the thermo-mechanical of beam and plates with considering the temperature-dependent physical properties.

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REFERENCES

Experimental Investigation of the Bending of Locally Heated AZ91B Magnesium Alloy Sheet

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Abstract— Automotive industry focused on reduction in weight to reduce fuel consumption and carbon footprint. This causes new studies on looking for materials has high specific strength. One of the current studies is concentrated on magnesium alloys. Its high specific strength is one of the most important reasons that make it popular. However, the low formability of magnesium alloys due to its hexagonal close packed crystal structure at room temperature limits their usage in automotive industry. In this study, bending of AZ91B sheet was investigated experimentally. The minimum permissible bend angle and localized thickness change were measured for cold and locally heated specimens. The effects of local heating are presented.

Keywords—Bending, Locally heating, Cracking, AZ91B, Springback

I. INTRODUCTION

The most important characteristic of magnesium is its low density, 1.74 g/cm3, which is only 1/4 of steel and 2/3 of Al. Magnesium has a higher specific strength and stiffness than many other engineering materials, including aluminum, steel and polymer-based composites. This low density and high specific strength makes it attractive for academic studies and industries. Aerospace, information and communication technology, medical and automotive are industrial areas increase the usage of magnesium or magnesium alloys. Although Mg alloys have low density and high specific strength, they have low formability at room temperature due to hexagonal close-packed (HCP) crystal structure. The main reason of restricted formability of Mg alloys is limited slip system at room temperature. Texture effect on plastic deformation of Mg alloy at room temperature was studied as in [1]. It was observed that Magnesium alloys has limited ductility and poor formability at room temperature due to insufficient number of operative slip and twinning systems. According to Von Mises slip system theory, as in [2], a polycrystalline must have least 5 independent slip systems to deform uniformly and without failure at the grain boundaries. However, Mg alloys have less number of independent basal slip systems than required at low temperature. To improve formability of magnesium and its alloys, non-basal slips system must be activated or deformation occurs by twinning. It is clear that the activity of a non-basal slip system, i.e., the critical resolved shear stress (CRSS) for non-basal slip, depends on solute atoms, precipitates as well as on temperature. The CRSS for prismatic slip at room temperature is about 100 times higher than that of basal slip, whereas at 300° C it is only four times higher [3]. Important effect of temperature on formability of magnesium alloy were discussed a lot of studies. Ebrahimi et al.[4] studied on flow behavior and microstructure evolution of AZ91 magnesium alloy during a thermo-mechanical process. The specimens were hot compressed at range from 350° C and 425° C at different strain rates and recrystallized grains nucleate along the pre-existing grain boundaries was investigated. Trojanová et al.[5] worked on plastic deformation of AZ91 in temperature range between 360° C and 420 °C at different strain rates. The maximum elongation of 584% was obtained at 420 °C and 1 × 10−4 s−1 for the sample aged at 380 °C with a corresponding value of the strain rate sensitivity m = 0.68. The tensile elongations of all samples exceeded 200%, which represents a substantial improvement over the poor room-temperature ductility, typical for magnesium alloys. Mabuchi et al.[6] worked on low temperature superplasticity in an AZ91 magnesium alloy processed by ECAE (Equal Channel Angular Extrusion). An AZ91 alloy with very small grain size of about 1µm was processed by ECAE. The alloy showed a large elongation of 661% at a low temperature of 473 K (0.57nm). Raghunath et al.[7] studied on flow stress modeling of AZ91 magnesium alloy at elevated temperature. The flow curve is constructed by flow stress data obtained from compression test conducted at different temperature and strain rate. Accurate flow stress model is crucial for investigating magnesium alloys deformation behavior at the elevated temperatures. An analytical method, which reflects temperature, strain and strain rate effect by introducing temperature-compensated strain rate (Zener–Holloman Parameter), is proposed in the study. This model has been applied on the experimental data and predicted flow stress curve match well with those measurements.

Taleghani et al.[8] studied on hot deformation behavior and workability characteristics of AZ91 Mg alloy powder compacts by performing hot compression tests. The true stress–true strain curves peaked at low strains, after which the
flow stress increased slightly or remained constant. The work hardening rate decreased with increasing deformation temperature or strain rate. According to the developed processing maps and the microstructures of the hot-compressed specimens, the optimum hot working window for AZ91 Mg alloy powder compacts was determined to lie between 275–325°C and 0.001–0.01 s⁻¹.

In this study, bending of AZ91B sheet was investigated experimentally. The minimum permissible bend angle and localized thickness change were measured for cold and locally heated specimens. The effects of local heating are presented.

II. EXPERIMENTAL STUDY

A. Material

As-rolled AZ91 (wt. % of Al-9%, Zn-1%, Cu-0.3%, Mn-0.13%, Mg-remainder) magnesium alloy sheet with thickness of 1.5 ± 0.05 mm was investigated in this study. Magnesium alloys are designated according to ASTM B275 (Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought) which indicates chemical components by weight. The first letter refers to the principal alloying element. The second letter refers to the second most significant alloying element. The first number refers to the nominal content of principal alloying element. The second number refers to the nominal content of the second most significant alloying element, as shown in Fig. 1. The last letter, A or B, differentiates between alloys of similar composition [9].

![Fig. 1 Designation of magnesium alloys](image)

Its crystal structure is one of the important causes to choose AZ91B as material. Magnesium alloys have low formability at room temperature because of the hexagonal closed packed crystal structure. This limitation restricts using of magnesium alloys at low temperature, but the search [10] shows that magnesium alloy exhibits high formability at high temperatures. Enhancement of formability of a material at elevated temperatures can be seen clearly in HCP. So choosing of material that has HCP crystal structure would be proper. Magnesium nearly ideal axial ratio is other cause to choose as a study material. The ideal axial ratio is 1.633 for Hexagonal Closed Packed crystal structure [11]. This value is 1.623 for magnesium (at 150° C) [12], This ideality would be provide advantages in theoretically calculations. The deviations in calculations will be 0.7% for magnesium. This value is 13.5% for cadmium. HCP crystal structure consists of three layers and totally 6 atoms in per unit cell. This compacted structure brings high atomic packing factor. Hexagonal closed packed atomic ratio is 74% (26% voids in unit cell). This ratio is 68% for Body Centered Cubic. Planes and directions are indicated by using 4 coordinate axes (a1, a2, a3 and c). This coordinate system is consist of 3 vectors that has 120° between themselves on a plane and one vector perpendicular to the plane as shown in Fig. 2 [12].

![Fig 2 HCP Crystal Structure Slipping Planes and Coordinate Axes](image)

Hexagonal Closed Packed crystal structure has 3 three slip planes which are basal slip plane, prismatic slip plane and pyramidal slip plane. HCP structure has less number of independent slip systems at room temperature so Mg and its alloy have poor ductility at room temperature. Ratio of Critical Resolved Shear Stress (CRSS) of basal plane to CRSS of non-basal plane is between 1:40-1:80 for single crystal models [13]. This low CRSS value is attributed low Schmid Factor. On the basal plane Schmid factor is too small due to orientation, so CRSS value on the basal plane is too small compared with non-basal plane. Slipping on the pyramidal slip plane is not expected at room temperature because to activate slipping in the c-axis direction high temperature is required.

B. Bending Die Set Up

Specimen was cut in same dimensions (60x225x1.5mm) perpendicular to rolling direction to observe cracking clearly. Bending was investigated as cold bending and locally heated bending by bending apparatus in Fig 3 and Fig. 4.
C. Experimental Procedure

Cold and locally heated bending was compared in terms of bendability as shown in Fig. 5. In cold bending specimens were bent at room temperature at angles of 60°, 65°, 67.5°, 75° and 90° for all specimens. In second step of experiment, pin has 13.5 mm diameter- which contact during bending process was heated up to 330°C by induction heating using RETERM RT-380M50 induction machine. Heated pin was placed on the apparatus. It was waited until to obtain regular temperature distribution on bending area of specimen. When regular temperature distribution observed at certain temperature level (this temperature level is about 150°C for this study). When pin and specimen reached to heat equilibrium at 150°C bending process was executed.

III. RESULTS AND DISCUSSION

In first step of experiment, specimens cut in same dimensions bent 60° at room temperature, small cracking was observed. When bent angle was increased to 65°, deepen in cracking can be observed explicitly on edge of the bending area. Cracking was regulated along bending line at 67.5°. Cracking was observed clearly at 75° along bending line. Fracture was observed at 90°. As a result cracking was observed on the specimens that were bent at room temperature.

In second step of experiment, specimens were locally heated and bent at same angles. Locally heated was executed by sheet metal with heat transfer. When specimens were locally heated up to about 150 °C and bent in same angles. Almost there was no cracking at 60°. Surface cracks initiated at 65°. They were obvious at 75° and deepened at 90°.

Thinning of specified points (as shown in Fig. 6) on bending line of sheet metals after bending was measured with ultrasonic thickness gauge. This thinning was illustrated in Fig 7 and Fig 8. In Fig. 9, thinning at 60° and 90° was compared for cold and locally heated bending. Locally heating has advantages in terms of formability but thinning on bending line observed.
Effect of locally heating on bending process at elevated temperature was investigated experimentally. The main conclusions derived from this study are as follows:

1) The locally heating is a successive method to prevent cracking in bending of AZ91B alloy. There is no cracking on bending area of locally heated specimen up to 75º bending, although all specimens were cracked at room temperature for cold bending.

2) Maximum thinning was observed at 90º for locally heated bending. The amount of thinning is about 9.1%. Therefore, thinning must take into consideration for locally bending process.

3) Commonly thinning increases directly proportional to the bending angle.

REFERENCES


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Drying of ionic hydrogels using fluorescence technique

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Abstract—Steady-state fluorescence (SSF) technique was employed for studying drying of poly(acrylamide-co-acrylic acid) (P(AAm-co-AAc)) composite gels for low and high pH. Disc shaped composite gels were prepared by free-radical crosslinking copolymerization of P(AAm-co-AAc). N, N'-methylenbis (acrylamide) (BIS) and ammonium persulfate (APS) were used as cross-linker and initiator, respectively. Pyranine 4 (4sPy) was introduced as a fluorescence probe. It was also observed that fluorescence intensity values increased as drying is proceeded. A phenomenological equation was introduced to determine the desorption coefficient, D of water molecules from drying hydrogels for various pH contents. Gravimetrical experiments for drying process were also performed. It was shown that diffusion coefficients for drying process D decreased as the pH values are increased.

Keywords—Hydrogels, pH, drying, fluorescence, diffusion

I. INTRODUCTION

Progress in material science stimulates the economy and greatly influences the living standards of a society. Intelligent materials are based on a new concept where the information science is introduced to the material. Today it is a challenging task to manufacture new multifunctional materials which possess intelligence at the material level. Intelligent materials can be referred in terms of three main functions: sensing changes in environmental conditions, processing the sensed information and finally making judgement (actuating) by moving away from or to the stimulus [1]. The innovative functions of these new materials are in many respects similar to those of living organisms. Biological systems continuously adapt to a dynamically evolving environment, while developing innate properties of homeostasis. The intelligent materials should also display these characteristics while maintaining harmony with the environment. The current generation of intelligent materials can be divided into two main parts.

1) Hard and dry materials, such as metals, ceramics and plastics. Intensive research is currently being devoted to compound semiconductors, dielectric ceramics, thin ferroelectric films and photovoltaic energy converters.

2) Soft and wet materials, such as electrorheological fluids, magnetic fluids and polymer gels.

In the last few years it is observed that a migration of interest and activity from the traditional hard materials towards soft materials, such as biomaterials, self-assembly materials, complex fluids and polymer gels. It is aware that soft materials will probably never replace hard ones, but their study has led to significant advances in areas such as artificial tissues, controlled drug delivery, molecular recognition, chemical valves, artificial muscles and chemomechanical energy conversion.

Polymer gels are unique materials in the sense that no other class of materials can be made to respond to so many different stimuli as polymer gels. The stimuli that have been demonstrated to induce abrupt changes in physical properties are diverse and include temperature, pH, solvent or ionic composition, electric field, light intensity as well as the introduction of specific ions [2-5]. In the last few years, these gels have become of major interest as novel intelligent materials. Many kinds of such gels have been developed and studied with regard to their application to several biomedical and industrial fields, for example, controlled drug delivery systems, muscle-like soft linear actuators, biomimetic energy-transducing devices and separation techniques.

In general, hydrogels were first described in the last century as networks that contain small fractions of polymers and large fractions of water; hydrogels maintain their shapes while they imbibe fluids or are dried [6]. The swelling and drying kinetics of hydrogels are very important in the pharmaceutical industry, in designing slow-release devices for drugs, in the agricultural industry for producing storable foods, and in medical industry in developing artificial organs. Hydrogel properties depend strongly on the degree of cross-linking, the chemical composition of the polymer chains, and the interactions of network and surrounding liquid. Especially, on the basis of their dramatic swelling and deswelling behaviours, pH-sensitive hydrogels are being utilized for new potential applications. Hydrogel properties depend strongly on the degree of cross-linking, the chemical composition of the polymer chains, and the interactions of network and surrounding liquid. Especially, on the basis of their dramatic swelling and deswelling behaviours, pH-sensitive hydrogels are being utilized for new potential applications. Hydrogels exhibiting pH-sensitive swelling behaviour have been usually swollen from ionic networks that can contain acidic or basic pendant groups. When these groups are ionized, a swelling osmotic pressure inside the material is built up, and fixed charges are trapped in the gel. As a result of the electrostatic repulsion, the uptake of solvent in the network is increased
In case of anionic polymeric networks, ionization takes place as the pH of the external medium rises above the pKa of the ionizable moiety [9]. The polymeric network becomes more hydrophilic as the degree of ionization increases and the polymer swells. One of the important types of anionic hydrogel is Poly(AAm-co-AAc), owing to the existence of hydrophilic –COOH and –NH2 groups, has the capacity to absorb large amounts of water. Poly(AAm) hydrogels can absorb relatively high amount of water; however, their swelling capacity is not sensitive to pH or electrolytes [10]. Also, due to the presence of hydrophilic carboxylic acid side groups, the swelling behaviour of these hydrogels is highly dependent on the pH of the surrounding medium [11]. Hence, poly(AAm-co-AAc) hydrogels have been investigated for use as adsorvents in water purification [12,13], insulin release [14], osteoblast adhesion [16] and drug delivery systems etc. [15,16].

The understanding of the phenomena occurring in the drying of these hydrogels is necessary for the designing of the entire process. Drying of hygroscopic solids is generally known to be a complex process because of simultaneous heat and mass transfer and variable physical properties of the materials [17]. Special polymers and hydrogels are highly hygroscopic and shrinking colloidal materials and the drying of these encompass many fields of technology. The quantity of bound water associated with polymer varies as per the internal structure of the macromolecule. Monomer and cross-linking agent proportions are responsible for both the porous structure and the pore size of the gel. An acrylamide derived hydrogel is a cross-linked network of polymer whose molecular weight is fairly high; it can absorb solvent (water), but is itself insoluble. During the water migration in drying process, shrinkage corresponds simply to the compacting of solid mass.

Using the fluorescence technique, a pyrene derivative was employed as a fluorescence probe to monitor the polymerization, aging and drying of aluminosilicate gels [18], where peak ratios in emission spectra were monitored during these process. Recently, we performed drying [19,20] kinetics in disc shape non-ionic PAAm hydrogels at various temperatures and cross-linker contents using by steady-state fluorescence technique. In this study we investigated the effect of pH during drying processes in poly(acrylamide-co-acrylic acid) P(AAm-co-AAc) ionic composite hydrogel by using fluorescence technique. Here 4sPy was chosen as an aromatic molecule since its emission spectra does not depend on pH. Change in fluorescence intensity of 4sPy was monitored during in situ drying processes of composite gels. It was shown that diffusion coefficient for drying process, DG decreased as pH values are increased. The gravimetric measurements for drying process were also performed to compare results found from fluorescence technique. It is expected that diffusion coefficient, D values measured by using fluorescence technique are at least order of magnitude much larger than the values measured by gravimetric technique, which may present the different behaviours of the gel. Segmental motion of the gel network can be monitored by using fluorescence intensity and monitors the swelling at a molecular level. According to the above argument, one may suggest that chain segments move much faster than the bulk polymeric material during volume phase transition process.

II. EXPERIMENTAL

Disc shaped ionic composite gels were prepared by free-radical crosslinking copolymerization of P(AAm-co-AAc). BIS (Merck) and tetramethylethylenediamine (TEMED, Merck) were added as a cross-linker and an accelerator, respectively. The initiator, ammonium persulfate (APS, Merck), was recrystallized twice from methanol. The initiator and pyranine 4 concentrations were kept constant at 7x10\(^{-3}\) M and 4x10\(^{-4}\) M, respectively, for all experiments. Composite gel prepared by using % 70 AAm (Merck) and % 30 AAc by dissolving them in 25 cm\(^3\) of water in which 10µl of TEMED were added as an accelerator.

The fluorescence intensity measurements were carried out using the Model LS-50 spectrometer of Perkin-Elmer, equipped with temperature controller. All measurements were made at 90° position and slit widths were kept at 5 nm. A disc-shaped gel samples were placed on the wall of 1x1 quartz cell.

III. RESULTS AND DISCUSSION

During drying process of PAAm hydrogel in air, as water release is increased, fluorescence intensity, \(I_0\) increases and the scattered light intensity, \(I_s\) decreases. Here the decrease in \(I_s\) corresponds to the decrease in turbidity of the drying hydrogel, so the corrected fluorescence intensity, \(I\) was defined as \(I_{corr}/I_s\). Figure 1a and 1b present the variation of \(I\) versus drying time, \(t_d\) during hydrogel drying for pH=4 and pH=10, respectively. It can be seen that as drying time, \(t_d\), is increased, quenching of excited pyranines decrease due to increasing of water release from drying hydrogel. In order to quantify these results, the collisional type of quenching mechanism may be proposed for the fluorescence intensity, \(I\) from the hydrogel sample during drying process, where the following relation can be used [18].

\[
I^{-1} = I_0^{-1} + k_q\tau_\alpha [Q]
\]  

Here, \(k_q\) is quenching rate constant, \(\tau_\alpha\) is the lifetime of fluorescence probe and \(Q\) is the quencher. For low quenching efficiency, \((\tau_\alpha k_q[Q]<1)\), Eq. (1) becomes

\[
I = I_0(1 - k_q\tau_\alpha [Q])
\]
If one integrates Eq. (2) over the differential volume \((dV)\) of the hydrogel from the initial, \(a_0\) to final \(a_\infty\) thickness and then, reorganization of the relation produces the following useful equation.

\[
W = \left(1 - \frac{I}{I_0} \right) \frac{V}{k_q \tau_0} \tag{3}
\]

Here, amount of water release, \(W\) is calculated over differential volume by replacing \(Q\) with \(W\) as

\[
W = \int_{a_0}^{a_\infty} [W] dV \tag{4}
\]

Where \(V\) is the volume of the hydrogel at the equilibrium drying state, which can be measured experimentally. \(k_q\) was obtained from separate measurements by using Eq. (3) where the infinity equilibrium value of water release, \(W\) was used at each temperature. Since \(\tau_0\) \((5\text{ns})\) is already known from the dry hydrogel, then \(W\) can be calculated from the measured \(I\) values at each drying step. The plots of the water release, \(W\) for the hydrogels dried for pH=4 and pH=10 are shown in Fig. 2a and 2b, respectively.

Here it has to be noted that drying phenomena in gels has not yet been completely modeled, because drying process is not as simple as swelling, at least in water. In this work drying process is tried to be simplified, but still it is not modeled by considering elastic forces of the gel. During drying, it is assumed that there are two regions exist in the gel, i.e. less concentrated region near the surface separates itself from the high concentrated region by a boundary which moves during drying towards the center of the gel and as the boundary moves, water molecules evaporates from the surface of the gel into air. Then, the behavior of \(W\) against \(t_d\) can be explained by considering a model in which diffusion occurs in two regions separated by moving interface \([21]\). The moving interface can be marked by a discontinuous change in concentration as in the absorption by a liquid of a single component from a mixture of gases or by a discontinuity in the gradient of concentration as in the progressive freezing of a liquid. Discontinuities have been observed in several practical systems, for instance when two metals interdiffuse \([21]\). The sharp advancing boundary is well known in many polymer–solvent systems, which are considered as a discontinuity for some purposes. When the diffusion coefficient is discontinuous at a concentration \(c\); i.e. the diffusion coefficient is zero below \(c\) and constant and finite above \(c\); then the total amount, \(M_t\) of diffusing substance desorbed from unit area of a plane sheet of thickness \(a\) at time \(t\), is given by the following relation.
\[ \frac{M_t}{M_\infty} = 2 \left( \frac{D}{\pi a^2} \right)^{1/2} t^{1/2} \]  
(5)

where \( D \) is constant diffusion coefficient at concentration \( c_1 \). Here \( M_\infty = a c_1 \) is the equilibrium value of \( M_t \). If one assumes that the diffusion coefficient of polymer segments in the gel is negligible compared to the desorption coefficient, \( D \) of vapor of water into air, then Eq. (5) can be written to employ our data in Fig. 2 as follows

\[ \frac{W}{W_\infty} = 2 \left( \frac{D}{\pi a^2} \right)^{1/2} t_d^{1/2} \]  
(6)

Here it is assumed that \( M_t \) is proportional to the amount of water molecules released, \( W \) at time, \( t_d \). Figure 3a and b give the plots of \( W \) versus \( t_d^{1/2} \) for pH=4 and pH=10, respectively where the fit of the data produced desorption coefficient, \( D_F \) which are listed in Table 1. It is seen that as pH is decreased \( D_F \) values present increase by predicting faster desorption of water molecules from drying PAAm hydrogels at lower pH.

On the other hand, by using gravimetric technique (Gravimetical experiments were performed at the same condition of fluorescence experiment), water desorption was also measured from the drying PAAm hydrogel. Measured \( D_G \) values are listed in Table 1, where it is observed that desorption coefficient increase as the pH is decreased. This result is expected since hydrogel segments and water molecules move much faster in gels swollen at low pH, which cause faster evaporation of water from the hydrogel.

Here it is seen in Table 1 that \( D \) values measured by using fluorescence technique are at least twice much larger than the values measured by gravimetric technique, which interested different behaviours of the gel. It is obvious that the fluorescence technique measures the behaviour of the microstructure of the gel, i.e. segmental motion can be measured by fluorescence because pyranine molecules are bounded to the polymer chains. However, volumetric and gravimetric measurements may provide us with the behaviour of the macroscopic environment. According to above argument, one may suggest that chain segments move much faster than the bulk polymeric material during swelling process.

<table>
<thead>
<tr>
<th>pH</th>
<th>( W_i ) (g)</th>
<th>( W_f ) (g)</th>
<th>( D_F )-drying ((x10^{-8}m^2/s))</th>
<th>( D_G )-drying ((x10^{-9}m^2/s))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.1589</td>
<td>0.0928</td>
<td>12.0</td>
<td>5.77</td>
</tr>
<tr>
<td>10</td>
<td>0.2532</td>
<td>0.1663</td>
<td>5.30</td>
<td>4.18</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

These results have shown that the steady-state fluorescence technique, which is quite powerful and inexpensive, can be used for real-time monitoring of hydrogel drying process. The empirical model was derived and used to determine the desorption coefficients for the drying process. It is observed that diffusion coefficients for drying process \( D \) decreased as the pH values are increased.
REFERENCES

Weight Reduction Study on BIW by Using Boron Alloyed Hot Stamping Solution of Front Frame Rail Instead Conventional HSS or AHSS Applications

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Abstract—With the increase of the performance requirements and homologative restrictions the correct way of choosing the right material on the related area is an inevitable manner for weight reduction of the vehicles. A hot stamped front frame rail which have roughly same performance with conventional cold stamped one was designed by using tailor welded and patch reinforcement. The part was optimized with full sized frontal crash (EUNCAP), full sized rear crash (Trias33) and fatigue simulations. Critic interferences-accelerations into the passenger cabin was considered for acceptance criteria of frontal crash, deformations on fuel system for acceptance criteria of rear crash and plastic deformations on the part, especially suspension fixing points, for acceptance criteria of fatigue test. At the end of all optimization the thicknesses of the system was designed as; first tailor welded part: 1.2mm, second tailor welded part: 2.5mm and patch reinforcement: 1mm. Also some design critics (such as laser cut holes and trims, seal and barrier application for eliminating water infiltration into the bare surfaces of the hot stamped part) was clarified to guarantee the performance of the part during lifecycle of the vehicle. With final condition new hot stamped system was weighted 5 kg and gained a 2 kg weight reduction.

Keywords—Front Frame Rail, Hot Stamping, Boron Alloyed Steel, Body Light Weighting, Frontal Crash, Suspension Fixing

I. INTRODUCTION

This document represents a weight reduction study and its application on the vehicle body to reduce total weight of the vehicle, energy consumption of the required material and finally CO2 emissions.

There are several type of materials and method to reduce total body weight. But the multi material concept and the selection of the correct material in correct places is very important for cost effective solutions. [1] Steel has every time widest usage area on body structure during material selection in multi material concept. Beside steel grades is increasing thicknesses there can need to use different processes like tailor welding. Using this type of processes to get more rigid structure like laser tailor welding and patch welding. With this type of processes is aimed to eliminate negative effects of the weight-thickness reduction of component. New front rail design verified with all aspect of performance requirements of the vehicle like crashworthiness and fatigue life of the vehicle.

Fig. 1 Steel grades in BIW design [3]

II. EXPERIMENTAL PROCEDURE

Front frame rail (Fig. 2) is a structural component on the underbody structure and has important performance requirements such as safety cage protection during frontal crash, fuel tank protection during rear crash, fatigue life during driving with the aspect of energy absorption which is coming the from the road through the front suspension. Thanks to process advantages of hot stamping process sheet metal mechanical properties increase highly and can be reached at 1500Mpa without any crack, wrinkles or spring back, with good microstructure well dispersed hardness. [4], [6]

A. Tailor Laser Welding & Patch Welding

To reach the high performance targets when optimising the thicknesses there can need to use different processes like tailor welded steel solutions and patch welding. Using this type of processes the thickness of the component can be adjusted with
different mechanical properties during the component section. [5]

For having lightweight body structure new front frame rail is designed by using hot forming material with tailor laser welded two different thickness 1.2 and 2.5mm. This rail is reinforced by patch welding with 1mm FEE 340 material. The section of the rail is optimised considering the crash performances and fatigue life of the vehicle. Especially suspension fixing point is reinforced with patch welding. The distance between the sheet metal parts on the patch welding area is 0mm as a process necessity. This situation decrease the inertia on this point but local rigidity across the fatigue load of the suspension fixing will increase.

Tailor laser welding of the sheet metals with the thicknesses 1.2mm and 2.5mm brings the advantage of optimisation of the component for the crashworthiness. With this process additional ~60g weight reduction is gained and also cycle time of the process is decreased. Basic weight reduction is provided with the elimination of matching surface which is using for spot welding area. Laser welding is designed for butt welding and there is no need for matching of the surfaces. Fig. 4 shows the comparison of the zones used for spot welding versus laser butt welding.

B. Cutting and Blanking of the Hot Stamped Part

One of the most important production problem of the hot stamped parts is cutting. At the end of the process hot stamped part has a yield strength between 950 – 1250 MPa and this value make the cutting operation almost impossible with conventional cutting tools or punch. Even if the using cutting operation with blanking tools or punch the tool life will be very short. In this case producers has to put up with high repair costs. These additional repairing cost is important but rather than the cost, repairing time of the tools cannot be accepted for serial production cases. To eliminate this problem can be used warm forming process for cutting or blanking operations. [7] Or directly, like this example, can be used laser cutting operation both for trim cutting and hole blanking. Laser cutting operation has a cost disadvantage respect to blanking operation. Also with laser cutting operations trim tolerances are higher than blanking. On trim lines part has to at least ±1mm tolerances. So the mating parts also can need to be redesigned with the tolerances of hot stamped parts not to have misaligning the holes or mismatching the periphery edges.

C. Forming of the Part

During the hot stamping process the heating temperature reaches to 900 °C and for an ideal martensit structure formation approximately it has to be cooled 30 °C/s till to 250 °C. Thanks to heating effect of the material part under the press condition can be formed easily. Steel part formability limits enhances drastically. This situation gives to designer an opportunity to design the parts with small radii and sharp corners. At the end of the process there is no expectation like spring back or wrinkles of the part geometry. Small radii and completely matching of the patch part on the front rail can
used to get final geometry of the part which guarantee performance requirements. As shown in Fig. 6 hot stamping part can be stamped within the acceptable limits of wrinkle and thinning. The deepest zone of the part has no any crack problem or excessive thinning problem. Without any form modification or radii relaxation on the geometry, same geometry cannot be stamped with cold stamping die without crack or wrinkle.

**D. Vehicle Virtual Validations**

Structure and mechanical characteristics of front frame rail is crucial for the safety performance of the vehicle. To be protected safety cage front rail has to good energy absorption characteristics and high mechanical properties. Generally these characteristics are obtained by using functionally graded strength (FGS). FGS structures are found by optimizing all of the crashworthiness and its deviation by the time of the crash impact (peak forces, max-min acceleration of the deformation, max displacement of the related zone in safety cage etc.) [8]

**Front Crash:** For the evaluation of the vehicle in Europe Market; within the Euro NCAP - European New Car Assessment Programme the vehicle crashes to a static barrier with 64 km/h velocity. Fig 8 shows schematically the regulation.

At the end of the test the deformations on the vehicle is controlled for validation of the vehicle. Basically there musn’t be interferences creating high risk for driver & passenger safety into the safety cage and the vehicle after crashing must let the passengers going out easily.

In the Table 1 can be found the interferences into the vehicle categorized according to critic areas for the driver.

**TABLE I**

<table>
<thead>
<tr>
<th>Part</th>
<th>Description</th>
<th>Material</th>
<th>Thickness</th>
<th>Yield Strength MPa</th>
<th>Tensile Strength MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Patch reinforcement</td>
<td>FEE 340 (HSS)</td>
<td>1.2mm</td>
<td>340 - 460</td>
<td>≥ 410</td>
</tr>
<tr>
<td>B1</td>
<td>1. Tailor welded part</td>
<td>HOT RIV 1500</td>
<td>2.5mm</td>
<td>950 - 1250</td>
<td>1300 - 1700</td>
</tr>
<tr>
<td>B2</td>
<td>2. Tailor welded part</td>
<td>FEE 340 (HSS)</td>
<td>1.2mm</td>
<td>340 - 460</td>
<td>≥ 410</td>
</tr>
</tbody>
</table>

Target 45 45 30 25 90 50
Achieved 16 29 7 20 72 27

New front rail is rigid enough to protect safety cage and limits the interferences. Buckling of the rail is located on the left of the vehicle because of the barrier impact side. On the right side the front rail seems with very few plastic deformations.

The interference values and other front crash results are positive, in the following Fig. 9 is shown the crash simulation.
Rear Crash: For the evaluation of the rear crash performance of the vehicle TRIAS 33 has been executed. TRIAS 33 basically controls the deformations on the fuel pipes and fuel tank. Within the TRIAS 33 a rigid barrier has been impacted with 52 km/h to the vehicle from the rear side. Following Fig 10 shows schematically the test condition.

The vehicle which contains hot stamped front frame rail is crashed by moving rigid barrier and controlled elastic and plastic deformation. The test is resulted as positive. Deformations on the body structure is shown in Fig 11 and 12.

Fatigue Performance: Vehicle with the hot stamped front rail part has been verified also with respect of fatigue life of the vehicle. For the fatigue life of the part the most critical effect comes from front suspension fixing points. On these points fixing element selection is very important and they must carry the force coming from road to the vehicle body structure without any structure fail. Fixing nuts are welded on the front rail by projection welding.

With these condition vehicle is analysed and investigated a good fatigue life conforming to vehicle targets.

Fig. 9 Frontal impact virtual analysis result

Fig. 10 Rear impact condition of the vehicle for TRIAS 33 validation

Fig. 11 Rear impact virtual analysis result – side view

Fig. 12 Rear impact virtual analysis result – bottom view

Fig. 13 Fatigue life analysis
E. Treatment of the Part and Corrosion Behaviour

Hot stamping part (or blank) is heated till to 900 °C to obtain austenite formation. The blank sheet needs to be transformed quickly to the forming die. If blank is selected without any protective coating there can be abrasive iron oxide layer on blank sheet. [9] There are two solution to eliminate this problem; 1- heating must be done in a protected zone from atmosphere, 2- selecting an appropriate coating on blank sheet. Within this study blank sheet selected with hot-dip aluminized coating.

III. CONCLUSIONS

In the present study within the BIW light weighting trials a new front frame rail is designed. It is inspected that functional graded strength structure formation is inevitable during the optimisation between thickness decrease and structural performance targets. For creating FGS alternative type of welding and reinforcing can be used. The virtual analysis showed that the new structure with new front frame rail reinforcement succeeded all safety and structural tests with 2kg decreased weight per vehicle.

The producers still has to use additional coating to protect abrasive oxide layer and the necessity needs further studies to optimize or completely eliminate this requisite.

REFERENCES

Weld Current Effect on the Tensile Strength of Cold Rolled TWIP980 Steel Joints Welded by Resistance Spot Welding

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Abstract—Recently, as a result of the development of new commercial steel sheets for applications in car body manufacturing, high manganese twinning-induced plasticity (TWIP) steel sheets are gaining popularity in automotive body structure applications. The use of steel sheets in the automotive industry inevitably involves welding, particularly after the cold forming. Resistance spot welding (RSW) is the most widely used joining process for steel sheets in car body manufacturing. The application of cold formed TWIP steels may require a more complete understanding of some issues associated with the resistance spot welding. So, in this study, the effect of weld current on the tensile shear strength of cold rolled TWIP980 steel joints welded by resistance spot welding was investigated. Prior to welding, TWIP980 sheets were cold rolled to 15% reduction in thickness. The welding processes were carried out using MFDC (Mid-Frequency Direct Current) resistance spot-welding machine connected to ABB robotic arm. Weld currents were chosen as 6, 7, 8, 9 and 10 kA and the other welding parameters were kept constant. Microstructural study and tensile shear tests of the joints were conducted. From the examinations, the post weld properties, such as the nugget size, indentation depth and tensile shear strength of the joints, were determined depending on the weld current.

Keywords—TWIP980 Steel; Cold rolling, Resistance Spot Welding; Weld Current; Tensile Shear Strength

I. INTRODUCTION

TWinning-Induced Plasticity (TWIP) steel is one of the candidate materials for the car body manufacturing because of its superior balance of ductility and strength. The TWIP steels contain a high amount of manganese, which stabilizes the austenitic microstructure at room temperature and decreases the stacking fault energy (SFE). In lower SFEs, mechanical twinning is highly promoted [1-5]. This mechanical twinning acts as strong barriers to dislocation motion [6]. There are numerous studies about microstructural and mechanical properties, effect of alloying elements, strain hardening mechanism, heat treatments etc. of TWIP steels [7-14].

Automotive sheet components inevitably involve welding, particularly after the cold forming. Resistance Spot Welding (RSW) is the primary sheet metal welding process in automotive body construction because of its low cost, easy automation, minimum skill requirements, and robustness to part tolerance variations [15,16]. However, because of the thermal cycle during the RSW process, the designed microstructure of sheet steels is destroyed. These microstructural deteriorations in the weld zone are highly dependent on the initial microstructure of the base metal and the welding parameters.

Saha and Park [17] have studied on optimization of double pulse schedule of cold rolled TWIP steel sheets by means of compact tension test (CTT). They reported that an increase in nugget size around 15% was observed compared to ISO standard schedule and conventional single pulse schedule. Spena et al. [18] have studied on the effects of welding parameters of RSWed TWIP steel sheets using Taguchi approach. They reported that the most effective welding parameter was weld current on tensile shear test. Saha et al. [19] reported the microstructure, mechanical properties and fracture morphology of RSWed TWIP steels. Yu et al. [20] identified the RSW characteristics of 1 GPa grade TWIP steel.

Recently, as a result of the development of new commercial steel sheets for applications in car body manufacturing, high manganese TWIP steel sheets are gaining popularity in automotive body structure applications. So, performing RSW of TWIP steel sheets after cold forming is an inevitable demand in the automotive industry. Therefore, it is important to study the welding behaviour of the resistance spot-welded joints of cold formed TWIP sheet steels. In the best of authors’ knowledge, quite a few investigations have been carried out concerning the effect of RSW process on the microstructure and mechanical behaviour of cold rolled TWIP steel sheets. The present investigation was aimed at studying the effect of weld current on the tensile shear strength of cold rolled TWIP980 steel joints. Microstructural study and tensile shear tests of the joints were conducted. From the examinations, the post weld properties, such as the nugget size, indentation depth and tensile shear strength of the joints, were determined depending on the weld current.
II. MATERIAL AND METHOD

In this study, as-received (1.3 mm) TWIP steel sheets were cold rolled around 15% reduction in thickness (around 1.1 mm) using cold rolling. All tests were conducted on cold rolled TWIP steel sheets. The chemical composition of the sheets used in this study is shown in Table 1. Tensile properties of as-received and 15% cold rolled steel sheets were also presented in Table 2. The ultimate tensile strength of TWIP sheet steel increased roughly 24% with 15% cold rolling and the total elongation value decreased around 57% with 15% cold rolling.

<table>
<thead>
<tr>
<th>Steel</th>
<th>Fe</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Al</th>
<th>Cr</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWIP Balance</td>
<td>0.28</td>
<td>15.6</td>
<td>1.06</td>
<td>1.89</td>
<td>0.564</td>
<td>0.1</td>
<td></td>
</tr>
</tbody>
</table>

The sheets were cut into the samples for the welding process with the dimensions 50 mm x 20 mm. Welding was performed by overlapping the samples using MFDC resistance spot-welding machine connected to ABB robot arm. The welding configuration can be seen in Fig.1. Copper alloy electrodes having the face diameter of 6 mm were used in the welding processes. The spot welds were performed with the weld current of 6 kA, 7 kA, 8 kA, 9 kA and 10 kA while keeping the welding time and electrode force constant at 250 ms and 2.25 kN, respectively.

In order to describe the microstructural characterization of the joints, the spot welded joints were cross sectioned through the weld nugget center using an electrical-discharge cutting machine. The microstructure was revealed using both Nital (3%) and Na₂S₂O₃ solution (10 g Na₂S₂O₃ in 100 ml H₂O), respectively. The optical microscopic studies were carried out by a Nikon DIC microscope under polarized light with a Clemex image analysis system. The tensile shear tests were performed with a fully computerized UTEST-7014 tensile testing machine in laboratory conditions using a constant strain rate of 3.33x10⁻³ s⁻¹. The nugget size of the welds was measured through the fractured specimens using Mitutoyo digital caliper. A ball ended Mitutoyo micrometer was used to measure the indentation on the spot welds. In addition, a scanning electron microscope (SEM) was used to describe the failure modes of the joints.

III. RESULTS AND DISCUSSION

RSWed joints exhibited three different microstructural zones: the fusion zone (FZ), heat-affected zone (HAZ), and base metal (BM) (Fig.2). BM microstructure consists of fine grained austenite including mechanical twins, with evident bands in the rolling directions. The HAZ has fairly coarse grained austenite including annealing twins. On the other hand, a typical coarse columnar dendritic structure existed in the FZ.

<table>
<thead>
<tr>
<th>TWIP Steel</th>
<th>Ultimate Tensile Strength Rm [MPa]</th>
<th>Total Elongation A [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>As-received</td>
<td>982</td>
<td>46</td>
</tr>
<tr>
<td>15% cold rolled</td>
<td>1220</td>
<td>20</td>
</tr>
</tbody>
</table>

The weld properties of the resistance spot welds fabricated with different weld currents (average values).

<table>
<thead>
<tr>
<th>Current [kA]</th>
<th>Time [ms]</th>
<th>Force [kN]</th>
<th>NS [mm]</th>
<th>Indentation [%]</th>
<th>Tensile Shear Load [kN]</th>
<th>SD</th>
<th>Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>250</td>
<td>2.25</td>
<td>5.54</td>
<td>11.16</td>
<td>10.49</td>
<td>0.38</td>
<td>Interfacial</td>
</tr>
<tr>
<td>7</td>
<td>250</td>
<td>2.25</td>
<td>5.80</td>
<td>14.96</td>
<td>11.18</td>
<td>0.75</td>
<td>Interfacial</td>
</tr>
<tr>
<td>8</td>
<td>250</td>
<td>2.25</td>
<td>5.87</td>
<td>22.50</td>
<td>11.91</td>
<td>0.17</td>
<td>Partial Interfacial</td>
</tr>
<tr>
<td>9</td>
<td>250</td>
<td>2.25</td>
<td>6.16</td>
<td>31.75</td>
<td>12.24</td>
<td>0.32</td>
<td>Button Pull-out</td>
</tr>
<tr>
<td>10</td>
<td>250</td>
<td>2.25</td>
<td>6.43</td>
<td>42.21</td>
<td>12.38</td>
<td>0.32</td>
<td>Button Pull-out</td>
</tr>
</tbody>
</table>

TABLE 1
THE CHEMICAL COMPOSITION (wt.%) OF TWIP STEEL SHEET USED IN THIS INVESTIGATION.

TABLE 2
THE TENSILE PROPERTIES OF AS-RECEIVED AND 15% COLD ROLLED TWIP STEEL SHEETS USED IN THIS INVESTIGATION.

TABLE 3
THE WELD PROPERTIES OF THE RESISTANCE SPOT WELDS FABRICATED WITH DIFFERENT WELD CURRENTS (AVERAGE VALUES). (NS: NUGGET SIZE; SD: STANDARD DEVIATION)
The weld properties, such as nugget size (NS), indentation depth and tensile shear load, are shown in Table 3. The relationship between the weld properties and weld current can also be seen in Fig. 3. The NS is one of the most important factors that determine the quality and the strength of the spot weld [21-24]. As shown in Fig.3a, the weld current is one of the main controlling parameters for the NS. With an increase in the weld current from 6 kA to 10 kA, the NS was increased from 5.54 mm to 6.43 mm owing to the increased heat input. Fig.3a shows that there is a strong linear correlation between the NS and the weld current; the NS increases almost linearly with increasing weld current. The spot weld that meets the requirements of the appropriate specifications should have a minimum nugget diameter of 3.5–4 times the thickness of the thinnest outside part of the joint [25]. The measured NSs for all weld current values was found to be acceptable, i.e. over five times the thickness of the outside part of the joint. An indentation has also a vital importance for weld strength and external appearance in automotive industry. With an increase in the weld current from 6 kA to 10 kA, the indentation percent was increased from 11.16% to 42.21%. Especially, it should be noted that 42.21% can be considered as high indentation for automotive industry. Similarly to the relationship between NS and weld current, the indentation depth increases almost linearly with increasing weld current owing to the enhanced expulsion phenomenon during RSW process with higher heat input. However, a decrease in weld strength should be expected with further increase in indentation depth over 42.21%.

The weld current affected the tensile shear load of the resistance spot-welded joints (Table 3 and Fig.3c). The tensile shear loads of the joints increased almost linearly with increasing weld current (Fig.3c). The tensile shear load of the spot-welded joints increased approximately 18% when the weld current was increased from 6 kA to 10 kA. This increase in tensile shear load of the spot welds can be attributed to the enlargement of the NS. On the other hand, as shown in Fig.3d, the tensile shear loads of the joints increased almost linearly with increasing NS. In the tensile shear tests, spot welded joints with lower weld current (6 kA and 7 kA) exhibited an interfacial failure mode, in which the fracture propagates through the weld nugget (Fig. 4a). The failure mode of the spot welded joint with 8 kA was partial interfacial, in which the fracture initially propagates through the weld nugget and then redirects through the thickness direction (Fig.4b). On the other hand, the spot welded joints with higher weld current (9kA and 10 kA) exhibited a full button pull-out failure mode referring to higher deformation energy, in which fracture occurs in the HAZ at the around of the spot weld (Fig.4b).
IV. CONCLUSIONS

The conclusions derived from this study can be given as follows:

- The weld zone of the cold rolled TWIP980 spot welds has three different microstructural regions: the fusion zone, heat-affected zone, and base metal. The grain structure in HAZ is quite coarser than that of base metal. In addition, HAZ includes only annealing twins, whereas the base metal has only mechanical twins. On the other hand, fusion zone has a typical coarse columnar dendritic structure.
- The nugget size, indentation depth and tensile strength of the cold rolled TWIP980 spot welds increase almost linearly with increasing weld current. The peak indentation and tensile shear load was obtained with 10 kA. However,
a decrease in weld strength should be expected with further increase in weld current depending on the increase in the indentation depth.

- There is a direct relationship between the nugget size and the tensile strength of the spot welded joints: The tensile strength of the spot welded joints increases with increasing nugget size.
- The spot welded joints with higher weld current (over 9 kA) exhibited a full button pull-out failure mode, providing high weld strength.

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The phase composition and microstructure of clinoptilolite by addition of Al-powder

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Abstract— In this study, the effect of Al-powder (up to 30% by weight) on the phase composition and microstructure for the clinoptilolite based porous ceramics is studied. The mixture was dry ground in a ball mill; it was shaped by uniaxial pressing at 50 MPa and later sintered at the temperatures of 1200°C for 1 hour under air atmosphere. The clinoptilolite is composed from silica and alumina, the silica with Al-powder being reaction sintering which leads to corundum and silicon product and their amount has been increased with the amount of aluminium additive in the composition. The amount of metal powder in ceramic matrix is strongly determined the microstructure of samples where the material being either glassy foam nature or open-cell microstructure. The significant open porosities (~30-37%) could be obtained with the high aluminium content (10-30% by weight). As the sample contained 10% by weight, corundum crystallization with some cristobalite and silicone is determined. At higher aluminium content the samples being corundum with silicon. The high stable phases indicated uniform porosities and with smooth pore wall surfaces could be obtained.

Keywords— Clinoptilolite, aluminium powder, porous ceramic, microstructure, corundum phase

I. INTRODUCTION

There have been great attentions to enhance the producing of alumina based engineering ceramics whose are high strength and hardness with high chemical stabilities. The attention is also focused on the fabricating the materials with more precisely and cheaply. The advanced structural and functional ceramics from the mixtures of Al-metal and ceramic powders is achieved by the reaction bonding and the reaction sintering processes. The powder processing of the metal-ceramic powder mixture greatly determined the type of reactions as well as the furthermore the properties of the final product.

During the milling, the metal component is more reactive to the aqueous and solid media when oxidation, hydrolysis or amorphization is occurred as well as being the mechanical alloying. The size of the metal particles significantly affects the microstructural homogeneity where difficulty in the oxidation during sintering leads to microstructural failures. On the other hand, the fine size of aluminium powder is very dangerous because of its high activity. The size of the metal oxide has greatly determined the microstructure since the newly formed alumina from oxidation of the Al-particles appeared at grain junctions in large particles and showed porous microstructure. It is necessary to use of good enough aluminium additive to achieve the structural and functional properties such as high green strength (strong Al/Al contact bridges) and low shrinkage (due to volume expansion when Al is oxidized to form Al2O3). Thermal treatment of the green bodies in air leads to the formation of alumina/high alumina-containing ceramics, the atmosphere used as reducing/vacuum leads to produce of alumina-aluminate alloys. The significant advantages of the processing lie in the low-cost starting materials, easy green machining, good wear resistance, improved fracture toughness as well as in a broad microstructural and compositional variability of the sintered compacts [1-3].

Mullite type refractory ceramic was produced through the reaction bonding of aluminium oxide process by an attrition-milled mixture of kyanite (Al2O3·SiO3) and sintering of the sample after compaction. Attrition milling creates significant particle size reduction and develops homogeneity of the kyanite-aluminium powder mixture. Nearly half of the aluminium powder was oxidized during milling. The sample is slowly heated to 1100°C in air, and after rapidly heated to 1600°C and held for 1 h. In the course of the oxidation-sintering process, the aluminium oxidizes to alumina through both solid-state and liquid-state oxidation of the milled aluminium metal. This highly reactive alumina combines with the silica that is expelled during the decomposition of the kyanite. A dense, equated fine-grain-size mullite was produced [4]. The addition of 5 wt% of metallic aluminium powder to a refractory composition (designed kaolin clay, andalusite-rich schist, red clay, miocene clayey maly and silica sand) has increased the technological quality of the refractory which increased the resistance to 59.9 MPa where relatively coarse particle size of andalusite rich schist has been used in the composition [5].

The effects of mechanical activation on the sintering of mullite produced from kaolin and aluminium metal powder was investigated with respect to porosities of the ceramic samples. It is found that the open porosities of the samples for 1 h (~20%) of milling are higher than those with 40 h (~1%) of milling [6]. The natural ceramic powder such as kaolin was used for the fabrication of ceramic membrane support by using Al-powder up to 16% weight percent. The mixture was pressed and sintered at 1250°C under air atmosphere. The porosities (28.5%), pore sizes (multi-modal, mean diameter: 2000 nm) and hydrophilic nature (contact angle: 50°) was found to increase with increasing percentage of aluminium. The high metal content in the kaolin matrix has enhanced the mechanical strength of the sample [7].
The synthesis of pure and porous mullite has been investigated from kaolinitic clay with aluminium powder (10.5 wt. %) by sintering in oxidizing atmosphere. The bodies obtained by reactive sintering at 1550°C have a high open porosity initiated during the oxidation of aluminium powder. This porosity increases when a small amount of magnesium powder (3 wt. %) is added. In spite of this high porosity the sintered bodies have a good mechanical cohesion [8]. A highly porous mullite–zirconia composite was investigated from the mixture of zircon and aluminium powders sintered at 1600°C in oxidizing atmosphere. The major oxidation reaction of Al proceeds with a liquid–gas mechanism that is suitable for producing low dense ceramics. TiO₂ addition accelerates the oxidation reaction of aluminium and obtained the high porosities (47%) [9].

The zeolitic ceramic powders have high potential to use for advanced ceramics by the reaction sintering processes. Since wetting of melted aluminium through the silicate matrix is strongly influenced by the presence of impurities. The natural zeolites such as clinoptilolite are high potential for use in ceramic-metal composites where the composition is contained high alkaline and alkaline earth metal cations such as Na⁺, K⁺, Ca²⁺ and Mg²⁺ [10][12], so as the oxides should be decreased the melting temperature more than the kyanite and kaolinite and facilitated fusibility that leading to high liquid phase sintering. By this way, glassy pore wall production is expected.

In this study, high alumina containing porous ceramic is investigated from the reaction-sintering of natural zeolite (clinoptilolite)-aluminium metal powder mixture through applied relatively low firing temperature (at 1200°C) is investigated with respect to the amount of Al-powder contaminations (up to 30 wt.%).

II. EXPERIMENTAL

The starting materials of this study were clinoptilolite-type natural zeolite (Manisa, Gördes, Turkey) and commercial pure aluminium (99% purity). The compositions of the clinoptilolite was analyzed by X-ray fluorescence and obtained as: 75.28% SiO₂, 11.85% Al₂O₃, 3.97% CaO, 2.71% Na₂O, 2.46% K₂O, 1.74% MgO, 1.63%Fe₂O₃, 0.14% TiO₂, 0.09% SO₃, 0.06% P₂O₅, 0.04% MnO. A laser size analyser (Malvern) was used for the particle size distribution determinations and the results are shown in Figure 1. The maximum size of the ceramic and metal powder was similar as 150 µm in size. The aluminium powder has narrow size (average size ~ 3 µm) and the zeolite has finer up to 170 nm in size.

The clinoptilolite and aluminium, mixed in the ratio of 9.5:0.5 to 7:3 by weight, was dry mixing in a ball mill for 5 min. The mixture powder was formed into a green body by uniaxial pressing into a cylindrical steel mould φ 30 mm under a pressure of 50 MPa. Later the samples sintered at the temperatures of 1200°C for 1 hour in an air furnace. The heating and cooling rates of the furnace was 10°C/min.

The crystalline phases of all the sintered samples were identified by X-ray diffraction (XRD) analysis using Rigaku Miniflex powder diffractometer. The measuring rate was of 2°/min. and the interval was of 20°-60°. The microstructure of the samples were investigated by SUPRA 40VP scanning electron microscope (SEM). Apparent porosity and bulk density were measured by water immersion technique according to Archimedes’ principle. Total shrinkage was how much the samples shrinks from its plastic state to its fired state and can be calculated using the following equation:

\[ \%TS = \frac{L_1 - L_2}{L_1} \times 100 \]

where, TS: Total shrinkage, L₁: Length of sample directly after pressing (mm), L₂: Length of fired sample at the temperatures of 1200°C (mm).

III. RESULT AND DISCUSSION

Figure 2 shows firing shrinkage of the clinoptilolite sample without and with AI-powder up to 30% by weight for the sintering temperature at 1200°C. The clinoptilolite without aluminium has the firing shrinkage of about 16.3%. As the sample contained 10% by weight of aluminium, it is observed that significant decrease in the shrinkage which is 6.4%, and after the shrinkage changed is no more with the increase of the aluminium content. The aluminium content between 20-30% by weight, the shrinkage is relatively low and remained constant; it is determined as 3.8%.

Figure 3 shows XRD patterns of the clinoptilolite sample without and with Al-powder. The clinoptilolite without Al-powder shows mainly two major crystalline phases: cristobalite and quartz. The clinoptilolite contained 5% by weight of Al-powder indicates a very small quantity of corundum and Si formation. The corundum and Si peak height increase as the Al-powder increased to 10% by weight. The high Al-powder mixture (20-30% by weight) indicated the crystallization occurred without cristobalite. The mixture with high aluminium content can be considered a corundum material with Si contamination. It may have a potential for use in the ceramic
industry because of its expected high thermal stability as well as high chemical resistance. A low firing shrinkage is observed with the high percentage of Al-powder contained material (see Fig. 2), it consist formation of the high stable phase structure such as corundum (see Fig. 3).

![Figure 2. Total shrinkage of the clinoptilolite sintered without and with Al-powder.](image)

![Figure 3. Phase compositions of the clinoptilolite sintered without (a) and with Al-powder for 5% by wt. (b), 10% by wt. (c), 15% by wt. (d), 20% by wt. (e), 25% by wt. (f), 30% by wt. (g), C: corundum, Cr: cristobalite, S: silicon, Q: quartz](image)

Figure 4a-f show the SEM micrograph of the fracture surface of the samples without and with aluminium for varied amount of metal powder additives. Without the aluminium, the vitrified zeolite phase is shown where some gas evaluation makes the material having some closed porosities. The SEM micrographs of the ceramic bodies reveal the better microstructural features of the ceramic body produced from the aluminium additives at 10% by wt. where it was observed a homogenous pore distribution and less local, massive vitrification of zeolite. As the increase of the amount of aluminium makes the material as high open porosities where the local mass parts changed to fine size of porosity containing parts (see Fig. 4c-g and Fig. 5). The high open porosities observed with the high aluminium contents may be the finer pores appeared between the large size pore connection points. It is found that the samples containing aluminium powder between 10-30% by wt. of aluminium are good enough for the sample to use as a porous filtering material.

![Figure 4. SEM Analysis of the samples from fracture surface where without and with different amount of aluminium additives; without aluminium (a), 5 % wt.(b), 10%wt.(c), 15%wt.(d), 20%wt.(e), 25%wt.(f), 30%wt.(g).](image)

Figure 6 shows the bulk densities of sintered samples without and with varied content of Al-powder. Low content of aluminium up to 10% by weight decreased the densities and after the densities slightly increased by the metal powder contents. The decrease of the densities is attributed that the formed porosities (see Fig. 4c-f and Fig 5). On the other hand, the slightly increase of the densities may be due to the high crystallization of the samples as corundum (see Fig. 3).
samples with high content of aluminium (15-30 % by wt.) show the ceramic material having more stable phase (corundum) with uniform porosities and with smooth pore wall surfaces.

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The authors acknowledge with sincere gratitude the financial support provided by the Dumlupinar University Research Project 2015-96.

REFERENCES


CONCLUSIONS

The addition of metallic Al-powder up to 30 wt.% on the phase composition and microstructure of clinoptilolite has have investigated for the sintering temperature applied at 1200°C in an oxygen atmosphere. The clinoptilolite without metal powder indicated glassy foam ceramics with less porosities as well as small pore sizes (~10-50 micron). As the metal powder addition with sufficiently amounts (10% by wt.) it makes the material with opened porosities with large sizes (~50 micron). The opened porosity of the sample is measured as 29.7%. The pore wall of the porous structure that is formed is uniform and smooth structure. The increase of the amount of Al-metal powders increased the fine size porosities where the massive vitrification of zeolite is disappeared and the finer pores being appeared. Increasing of the aluminium content leads to increase of the number of fine pores in the ceramic structure. The current results show that the clinoptilolite requires at least %10 by wt. of Al-powder to obtained the samples as capillary porous material where these are significant founding’s: (i) well spreading and wetting, (ii) good enough opened porosities and (iii) sufficiently crystallization of the samples with corundum phases. The milling of the clinoptilolite with Al-powder and the applied sintering temperature are the main factors whose will be further studies to optimization of the capillary porous formation.
Improving Die Filling Utilizing Bi-Directional Forging Process

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Abstract—Precision forging (net or near net shape) process is preferred in manufacturing automobile components due to high productivity, closer dimensional tolerances and minimal material waste. The basic drawback of the process is the requirement of higher forging load and encountered tool stresses. This limits the parts size and shape complexity. In this study, uni-directional and bi-directional forging processes are compared in terms of the forging load and die filling for U-shape axisymmetric part. The finite element analysis package (DEFORM) were used to simulate the process, and an experimental work was carried out for verification of the simulation model. A double acting servo press was used for the bi-directional forging. The movement of the top and the bottom punches of the press can be accurately controlled by the servo drive units. The results show that the forging load asymptotically increases at the final corner filling stage. The required forging load is considerably reduced by using bi-directional step loading. The unfilled area at the corner of the U-shape axisymmetric forging is minimized with lower punch load.

Keywords— Precision forging, die filling, finite element method, bi-directional forging, servo-drive press.

I. INTRODUCTION

Enclosed die forging has been developed since the 1970s, which uses one-ram or multi-ram as punches to press the billet in a pre-enclosed die to form a complicated shape forging without flashes [1,2]. As compared with the conventional flashless die forging, in which the billet is compressed between the upper and lower dies, the die cavity can be filled under a lower forming load owing to the reduction of the contract area between the loading punch and the billet material. But as the billet material fills the die cavity, the forming pressure increases sharply. Therefore, it is very important to reduce the forming pressure at the final stage of the process [3-5].

Moreover, the material flow in the case of fully-enclosed die forging is more complicated and difficult to predict. The forging defects (laps, folds, non-filling of dies, etc.) tend to appear. This result in the production of forgings with defects these are unsuitable for subsequent machining.

With recent advancements in software development and the availability of more powerful computers, numerical methods, especially finite element method has been developed. The finite element analysis (FEA) packages have enabled this entire forging process to be simulated, while simultaneously predicting all the necessary stress–strain states in both die and workpiece [6]. Recently, there has been a growing demand for developing enclosed die forging using the servo-press for the forging industry across the world. The development of servo-press realizes the complex and flexible press motion [7-10].

Kawamoto et al [11] focused on utilizing servo die cushion as a back pressure load generator to determine its effect on shape accuracy of the formed part and total forming load in cold forging. They have shown that the back pressure enabled better die filling with lower load. Yetkin et al [12] have shown that the forging load can be reduced and the metal flow can be improved by using bi-directional loading for H-shape axisymmetric part.

In this study, uni-directional (top punch movement), bi-directional (bottom punch movement together with the top punch) and bi-directional step (bottom punch and top punch movement, subsequently) forgings were compared in terms of forging load and die filling under various friction conditions. The initial work was done by using plasticine and the finite element (FE) model was verified. The U-shape axisymmetric forgings of Aluminum 1100 were simulated by using the FEA model and the results were presented.

II. FINITE ELEMENT MODELING

Although, many commercial finite element software packages are available, Deform was used in the study, because it is especially designed for simulation of metal forming processes. Using the rotational symmetry of the U-shape forging, axisymmetric analyses were performed. The die was considered as rigid and the workpiece was modeled as elasto-plastic materials. The dimensions of the preform and the final shape of the forged product are shown in Fig. 1 and Fig. 2, respectively. Three loading conditions were performed as they called uni-directional, bi-directional and bi-directional step loading. The dimensions of the billet were calculated from the final forging using the volume constancy. For the models 5196 elements were formed by using automatic mesh generation. Lagrangian incremental type and the Newton-Raphson Method were used for the solver and the iteration method, respectively. DEFORM uses the AMG (Automatic Mesh Generator) to solve problems of large deformation and to automatically provide an optimized re-meshing capability.
The speeds of the top and bottom dies were chosen as 0 and 1 mm/s according to aforementioned three loading conditions. Because of symmetry, only right one side of the model was used for the FEM simulation to reduce the calculation time.

![Fig. 1 Cylindrical billet for U-Shape Forging](image1)

![Fig. 2 Final geometry of U-shape forging](image2)

**III. EXPERIMENTAL STUDY**

**A. Plasticine specimen preparation**

For the verification of the finite element simulations, a physical modeling technique was used. Due to the capacity limitation (20 kN) of the servo-press used in the study, plasticine was chosen as a modeling material. The true stress-true strain diagram of the plasticine [12] is given in Fig. 3.

In order to make plasticine softer, it was heated to 50°C. Then it was subjected to repeated rolling and folding processes to remove any cavities formed.

A steel tube having 49 mm internal diameter and 50 mm length was completely filled with plasticine dough. Before filling, the internal surface of the tube was dusted with talcum powder in order to prevent sticking. Then the plasticine was pushed out from the steel tube and cut out to pieces having 12.8 mm height.

![Fig. 3 The true-stress true-strain diagram of the plasticine.](image3)

**B. Forging Press and Die Set**

The servo-press shown in the Fig. 4 has two movable punches (top and bottom) driven by two separate servo motors. The maximum capacity of the servo-press is 20 kN. Load cells and linear encoders are attached to the servo-press to plot load-stroke diagram. The die is fixed on the press bed.

The U-shape forging die set (see Fig. 5) consist of four main parts; a container, a bottom punch and two top punches. The parts are made of plexiglass and the dimensions are same as the components used in finite element model.

![Fig. 4 Photograph of the servo-press.](image4)

**C. U-Shape Forging**

By using the servo-press and the plexiglass die set, the plasticine preforms were forged to U-shape. In the forging processes talcum powder was used as the lubricant. Three loading conditions are schematically shown in Fig 6. The speed of the punches (top and bottom) was chosen as 1mm/s for all loading conditions.
IV. RESULTS AND DISCUSSION

A. Plasticine Simulations and Experimental Verification

The experimental and finite element results of load-stroke diagram are shown in Fig 7. The experimental measurements are given by symbols on the diagram. The results revealed that the finite element results and the experimental ones are in a very close agreement. This is verifying the finite element simulations where the friction factor was taken as 0.01.

The maximum forging loads for uni-directional and bi-directional forging conditions are very close to each other as 580 N and 520 N, respectively. The load in bi-directional step loading is considerably lower than the others. The maximum load in step 1 is 300 N and the maximum load in step 2 is 360 N.

B. Al-1100 Simulations

In order to show the effect of loading conditions (uni-directional, bi-directional and bi-directional step) in forging processes, finite element simulations were carried out for aluminum 1100. The material data for aluminum 1100 was taken from the Deform database. The load-stroke diagram of U-shape forgings for friction factor \( m = 0.4 \) is given in Fig 8.
The maximum forging loads for uni-directional and bi-directional forging conditions are very close to each other as 1020 kN and 990 kN, respectively. The load in bi-directional step loading is considerably lower than the others. The maximum load in step 1 is 274 kN and the maximum load in step 2 is 562 kN. The Fe results are summarized in Table I for all loading conditions.

### Table I
FE results for U-shape forgings of Al-1100

<table>
<thead>
<tr>
<th>Loading Condition</th>
<th>Top Punch Stroke (mm)</th>
<th>Bottom Punch Stroke (mm)</th>
<th>Maximum Forging Load (kN)</th>
<th>Unfilled Area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uni-directional</td>
<td>7.8</td>
<td>0.0</td>
<td>1020</td>
<td>0.086</td>
</tr>
<tr>
<td>Bi-directional</td>
<td>3.9</td>
<td>3.9</td>
<td>990</td>
<td>0.213</td>
</tr>
<tr>
<td>Step1</td>
<td>0.0</td>
<td>7.6</td>
<td>274</td>
<td>9.197</td>
</tr>
<tr>
<td>Step2</td>
<td>0.6</td>
<td>0.0</td>
<td>562</td>
<td>0.078</td>
</tr>
</tbody>
</table>

For various friction factors (m), the maximum forging load is given in Fig 9. It can be seen from the figure that the maximum load in uni-directional and bi-directional forgings were higher than the bi-directional step forgings for all friction conditions. This is because of the material flow characteristics during forging. In uni-directional and bi-directional loading conditions, all mass of the body is forced to move in order to fill the die, but in bi-directional step condition a small portion of the mass is subjected to move to fill the die. The corresponding material flows for aforementioned loading conditions are shown in Fig 10.

![Fig 9 Maximum forging load versus friction factor, m.](image)

![Fig 10 Material flow during a) Uni-directional loading b) Bi-directional loading and c) Step Loading](image)

The die filling characteristics of the three loading condition is also given in Table I. The unfilled areas (see Fig 11) for all conditions were determined from the FE model and the unfilled area and corresponding forging load is presented in Fig 12. The improvement in die filling and the reduction in forging load in bi-directional step loading are obvious.

![Fig 11 The die filling and the unfilled area.](image)
V. CONCLUSIONS

The followings can be concluded from the experimental studies and FE simulations:

- As the FE model is verified, the plasticine can be used as a physical modeling material for forging.
- The forging load asymptotically increases at the final corner filling stage.
- The forging loads for all loading conditions are increasing with friction.
- The required forging load is considerably reduced by using bi-directional step loading. The unfilled area at the corner of the U-shape axisymmetric forging is also minimized with lower punch load.

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REFERENCES

Burst Failure of Nano-Silica Added [±55]₆ Filament Wound BFR/Epoxy Composite Pipe

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Abstract— Filament winding process commonly is applied for high pressure containers, gas and liquid transfer line, mobile bridging components and military applications. In this production methods, glass fiber generally used in but, mechanical properties of glass fibers are lower than Kevlar, basalt and carbon fibers. Although carbon and kevlar fibers have high mechanical properties, their costs are so high. Therefore, basalt fibers, having high mechanical properties than glass fibers and low cost are preferred and gotten by gaining the significant for the polymer composites as reinforcement material. To improve the mechanical properties of composites especially for polymer matrix, the matrix polymers have been modified with nanoparticle addition. SiO₂ nanoparticles have low cost and ensuring fine mechanical properties. In this present study, the static internal pressure tests were carried out to 4%wt SiO₂ nanoparticle added [±55]₆ BFR and pure [±55]₆ BFR ±6 layers filament wound epoxy composite pipes under open ended conditions. To find possion ratio and young modules of composite pipes strain gauges were used. At the end of experiments, strength and failures of SiO₂ nanoparticle added BFR and pure BFR composite pipes were investigated. It was observed that SiO₂ nanoparticle improved the hoop tensile strength of BFR composite pipes by 29% increase and affected the damage mechanisms.

Keywords— Basalt fiber, SiO₂ nanoparticle, composite, filament wound, mechanical properties.

I. INTRODUCTION

Basalt fiber reinforcement for polymer composites is increasingly used in the industry and plays a significant role in engineering polymer composites for many industrial applications. These reinforcement materials are generally used in high pressure containers which gas and liquid gas such as natural gas, hydrogen gas are deposited, gas transfer pipes, mobile bridging components, trusses, bridge piers and other applications etc. These reinforced composites have high strength-to-weight ratio and fine corrosion resistance [1-3]. However, it still need to widely usage for many application like automotive, aircraft and marine parts and excluded the high pressure application as reinforcement materials. Composite applications for gas cylinders are widely available on industry and they have many advantages and disadvantages. The weight of metal cylinders is an important disadvantage. The weight of a cylinder is reduced by using the reinforced polymers instead of metals. These cylinders maintain their durability due to their high strength and light weight epoxy matrix impregnated carbon fibers used. However, high price and current shortage of carbon fiber cause to high manufacturing cost. Basalt fiber has higher mechanical properties than E-glass fiber and cheaper than carbon fiber[1, 3-4]. These advantages could be a good alternative for gas storage vessels and pipes. Basalt fiber is readily available natural materials and produced from volcanic rocks that are found worldwide. Basalt fiber is environmental and nonhazardous materials. For high pressurized pipes, the filament winding method commonly used to produce the composite pipes to provide the high strength. The filament winding process allows a thermost resin-impregnated glass, carbon and basalt reinforcement to be wrapped around a suitable mandrel. The resin-impregnated fiber bundles wrap over the rotating mandrel and orientated according to ± lay-up angle to form the designed reinforced pipes. After that winding process, the component is cured under the defined temperature. Mechanical properties of the filament wound parts do not just depend from composition of component material. In addition, process parameters like winding angle, fiber tension, resin type and curing cycle effects the mechanical properties of filament wound parts [4-6]. The usage of the nanoparticles to improve the mechanical properties of polymer composite, is widely increased and gotten important for scientific people and industry. And so, many studies have been executed about the nanoparticles applications on polymer composites. In the polymer composite studies, carbon nanotubes, SiO₂, Al₂O₃ nanoparticles and nano clay are the best preference for researchers [7-8, 10]. Deng et al. (2007) studied on the fracture toughness of 0, 2, 4, 6, 8wt% SiO₂/Epoxy nanocomposites. They founded that silane modification provide the easy dispersion in the epoxy matrix material. They determined that the fine fracture toughness are attained at 4wt% SiO₂/Epoxy nanocomposites. They proved this definition with TEM analysis [8]. Sadej-Bajerlain et al. (2011) conducted to 0, 2, 4, 5, 10%wt Aerosil7200 and AerosilR711 silane surface modified SiO₂/Epoxy nanocomposites. The defined that 4%wt SiO₂ nanoparticle addition to epoxy matrix shows the best dispersion than other additions with AFM tests and TEM analysis [9].

In this study, we aimed to investigate experimentally burst failure of 4wt% SiO₂ nanoparticle added and pure [±55]₆ Basalt/Epoxy filament wound pipes under internal pressure at
open ended condition. Whitening and final bust failures of 4wt% SiO\textsubscript{2} nanoparticle added and pure BFR pipes have been observed.

II. MATERIAL AND METHOD

Basalt fiber with 400 Tex (BFR) and 11-13µm diameter is used as reinforcement and Ciba Geigy Bisphenol-A Epoxy CY225 resin system is used as matrix. As nanoparticle, SiO\textsubscript{2} nanoparticle which is 650g/m\textsuperscript{2} SSA and 15 nm mean diameters particle size has been used. 4wt% SiO\textsubscript{2} nanoparticle was added to epoxy matrix of BFR composite. After adding SiO\textsubscript{2} nanoparticle to matrix, the mixture have been stirred by sonicator during 20 min, and then, 40wt% curing agent added to the mixture and mechanically stirred by mechanic mixer during 5 min(Fig.1). End of the mixture processes, SiO\textsubscript{2} nanoparticle added mixture was placed into the filament winding machine resin chamber. 4wt% SiO\textsubscript{2} nanoparticle added and pure [±55\textdegree] Basalt/Epoxy filament wound pipes are produced at the filament winding facilities of commercial filament winding company. The wet winding method used for the production of the composite pipes with ±55 lay-up. For the geometry of composite specimen, ±6 layers of reinforcement, 2.63mm of thickness, 72mm inner diameter and 300mm length of specimen [10].

III. RESULTS AND DISCUSSION

Burst failure and damage formation of 4wt% SiO\textsubscript{2} nanoparticle added and pure [±55\textdegree] Basalt/Epoxy filament wound composite pipes were investigated with internal pressure experiments. End of the internal pressure hoop tensile strength of 4wt% SiO\textsubscript{2} nanoparticle added and pure [±55\textdegree] Basalt/Epoxy composite pipes are give in Fig. 2.

Fig. 1 a) SiO\textsubscript{2} nanoparticle mixing processes b) internal pressure test apparatus [10].

Open ended internal pressure test apparatus are given in Fig. 1b. According to ASTM D2992 standard. To determine other mechanical properties, axial and tangential LY13 type strain gages were placed on midpoint of composite pipes[10].

From the observation of during the experiment, the first failure sign was the formation of whiting line which stem from debonding failure along the basalt fiber oriented direction on ±55\textdegree filament wound BFR pipes. This failure occurred and progressed as thin white lines parallel to fiber direction due to the departure of fiber from matrix all along fiber bundle. As increasing internal pressure, debonding failure have been concentrated on fiber bundle by increasing and end of critical accumulation of debonding failure on same bundle, layer separation as called the delamination have been occurred. More and more increasing pressure increased swelling of pipe at center zone and so diameter of pipe especially at center zone extended. In addition the pipe length got short by increasing pressure. The whiting failure firstly were seen about 375-410 MPa stress values. End of step, basalt fibers were exposed the last failure by tearing as fiber breakage with burst at 595 MPa. These failure mechanisms are indicated on BFR composite pipe in Fig. 3. [10].
TABLE I

Mechanical properties of SiO$_2$ nano-particle added and pure [±55]$_6$ Basalt/Epoxy composite pipes [10]

<table>
<thead>
<tr>
<th></th>
<th>Pure</th>
<th>4%wt SiO$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winding Angle (ϕ)</td>
<td>±55°</td>
<td></td>
</tr>
<tr>
<td>Hoop Tensile</td>
<td>595</td>
<td>769</td>
</tr>
<tr>
<td>Strength, σ$_T$  (MPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elasticity</td>
<td>26.6</td>
<td>31.4</td>
</tr>
<tr>
<td>Module, E (GPa)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poisson Ratio, ν = $-\varepsilon_z / \varepsilon_x$</td>
<td>0.72</td>
<td>0.70</td>
</tr>
</tbody>
</table>

When Samanci’s study were investigated, whiting failure and burst failure were observed about 100 MPa and 405 MPa stress values respectively and elasticity modules were found to be about 23.17 GPa[11]. Our experimental results show that the whiting and burst failure of BFR pipes has higher than GFR pipes as well as elasticity of BFR pipes. Burst failure of BFR pipes are presented in Fig. 3. When Internal pressure tests were applied 4wt% SiO$_2$ nanoparticle added [±55]$_6$ Basalt/Epoxy composite pipe, similar observations just as failure mechanism of [±55]$_6$, Basalt/Epoxy composite pipe have been seen as near as 733 MPa hoop tensile strength. After this strength, SiO$_2$ nanoparticle added BFR composite pipe have been started to bend like three point bending test. This bending of SiO$_2$ nanoparticle added BFR composite pipe have been continued as about 769.2 MPa hoop tensile strength [10]. In this strength of composite pipes, fluid jets failure end of the forming pin holes into layers were occurred on different regions caused by accumulation of debonding, delamination and fiber breakage failures. Fluid jets occurred on composite pipes is matrix failure. When the debonding and delamination failures defined as matrix failures concentrate on fiber bundle, layer and interlaminar layer by accumulating, and reach the critical levels, pin hole matrix damages form into the layer and then fluid jet occurs as final failure given in Fig. 4[5, 10,12].

![Fig. 3 The final failure of [±55], filament wound Basalt/Epoxy composite pipes.](image1)

![Fig. 4 The final failure of 4wt% SiO$_2$ nanoparticle added [±55], Basalt/Epoxy composite pipes.](image2)

When compared 4wt% SiO$_2$ nanoparticle added and pure [±55]$_6$, Basalt/Epoxy composite pipes each other by considering hoop tensile strengths and final failure of composite pipes, SiO$_2$ nanoparticle addition increased the hoop tensile strength of composite pipe and fluid jets failure occurred instead of burst failure which occurred on pure [±55]$_6$, Basalt/Epoxy composite pipes. It was commented from this results that SiO$_2$ nanoparticle retarded the forming nano, micro and macro scale matrix cracks by providing fracture mechanism of SiO$_2$ nanoparticles like crack pinning, crack tip blinding, crack bowling and branching, retarding of crack occurrence and propagation, local plastic deformation and increasing the interface area[10-13].

IV. CONCLUSION

As results of experiments of open ended internal pressure, the mechanical properties of 4wt% SiO$_2$ nanoparticle added and pure [±55]$_6$ Basalt/Epoxy composite pipes were determined and compared eachother. Obtained inferences from experiments can be itemized below.

- The increasing internal pressure increase the debonding and delamination matrix failure and the first whiting failure which sign of debonding and delamination were seen about 375-390 MPa for pure [±55]$_6$, Basalt/Epoxy composite pipes. For 4wt% SiO$_2$ nanoparticle added [±55]$_6$, Basalt/Epoxy composite, accumulated whiting failures along the basalt fiber bundles were seen about 733MPa.
- The final failure occurred with burst of composite pipes of pure [±55]$_6$, Basalt/Epoxy composite pipes were observed at about 595 MPa the hoop tensile stress value and for the final failure as fluid jets of SiO$_2$ nanoparticle added [±55]$_6$ Basalt/Epoxy composite, the average hoop tensile strength have been seen at 769 MPa. And so, it’s the average increase was 29%
higher than \([±55]_6\) Basalt/Epoxy composite. SiO\(_2\) nanoparticle addition provided \(±18\) increase to \([±55]_6\) Basalt/Epoxy composite.

The usage of SiO\(_2\) nanoparticle for BFR pipes is very alternative application according to provided their mechanical properties which given above. The cost of BFR composite pipes by adding nanoparticles are lower than CFR (Carbon Fiber Reinforced) composite pipes and can ensure higher mechanical properties than CFR composite pipes. For gas transport line and liquid gas storage SiO\(_2\) nanoparticle added BFR composite pipes and vessels can be applied as safely.

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References

Potential Applications of Nano-Silica Particles in Civil Engineering

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Abstract—Concrete is irreplaceable material in civil engineering world owing to its superior characteristics like strength, moldable, cost-effective and available components that result in widespread utilization. Growing concerns for carbon dioxide (CO₂) emission manipulate concrete designs for more environment-friendly mixtures bearing in mind that cement is responsible for 7% of overall (CO₂) emission. Production of large amount of cement can be limited by designing long-lasting concrete applications that directly contributes to sustainable development. Recent developments in nanotechnology have led to exploitation of nano-scale products for cementitious composites that exhibit high performance and durable properties. Among nano-scale products, nanosilica materials present unique benefits in cementitious-based systems compared to conventional additives. The purpose of using ultra-fine nanosilica particles in cementitious composites is to improve fresh and hardened properties of composites. Taking into account that there is a link between the micro-scale structure and bulk structure of material, it is quite important to unite both scale in engineering manner. For this reason, researchers study to understand fundamental science of nanosilica on pozzolanic reaction kinetics, morphology and hydration structure in order to control properties at nano-scale that can make radical changes in bulk properties. In this paper, utilization of nanosilica powder in cementitious composites was extensively reviewed considering the wide range of research that were undertaken to enhance performance of cement-based materials. In addition to general approaches in nanosilica applications, some issues that are required to be addressed were summarized in order to take full benefits of nanotechnology. Future challenges in the use of nanosilica in civil engineering applications were considered and potential alternative applications were also discussed within the scope of this paper.

Keywords—Civil engineering, Material science, Sustainable materials, Cementitious composites, Nanosilica

A. Introduction

Civilization in parallel with economic development has always been close relationship with the civil engineering. It is known that concrete is a dominating material in civil engineering compared to other construction material in terms of its production amount and vital importance on structures. Over a century, huge amount of Portland cement and aggregates are required in order to develop infrastructures in the forms of airports, dams, bridges, buildings, etc. which play essential roles in the human life. In last few decades, attention was drawn by production of cement particles which cause detrimental effects to atmosphere. Also, raw materials such as lime, clay and coal that is used in cement kiln trigger reduction of productive soil and forest lands. In cement market today, production of cement has reached to 4 billion ton causing 7% of all CO₂ emissions in the world [1]. Construction industry has also some initiatives to barrier CO₂ emissions and control the production of cement along with the other industries [2]. However, considering the increase of cement production, concrete applications should serve within its designed lifespan beside other environmental efforts.

In European design codes, lifespan of reinforced concrete structures is accepted as 75 years [3]. However, a great deal of structures are become out of service even before their half of lifespan due to mechanical loads and environmental effects. Short lifespan of structures, rehabilitation and reconstruction of damaged structures and detrimental effects of these activities cause great expenses for economy. It is obvious that beneficial elements are required to create sustainable construction industry. For this reason, concrete, the most important composite material in construction world, should exhibit longer durability properties as well as providing energy efficiency. Deterioration of concrete is attributed to mechanical, physical and chemical interactions that can occur in different ages of concrete. Cracks can critically damage the concrete due to brittle property of concrete. Damages consist of durability problems such as corrosion that leads to rigidity reduction of concrete, freeze-thaw cycles, alkaline-aggregate reactions, sulfate attack, aggressive water attacks, acidic attacks etc. Only few studies, deal with all of the abovementioned issues, exploit the advanced materials technology. In these studies, scientists take advantage of nanotechnology products that contain many novelties. Nanotechnology means the controlling, producing and understanding of materials at nano scale (below 100 nm, 1 cm = 10⁻⁹ nm) in order to create new functionalities and properties for materials [4]. Nanomaterials draw interest in construction materials world and many studies are carried out because of superior functional characteristics of nano products. In civil engineering, nanotechnology refers to use of materials at nanoscale in order to engineer bulk properties of that material. Therefore, nano-engineered concrete provides many benefits such as strength, performance and durability at once compared to conventional
concrete. Progress of high performance concrete was illustrated in Figure 1.

B. Influence of nanosilica in cement based composites

Micro and nano-scale silica particles fill between cement particles and act as filler effect. Strength of materials can be improved by designing accurate composition and concrete mixtures can be produced with low water/cement ratio. Besides physical effect, nano silica particles have much more pozzolonic reaction effect compared to silica fume. For this reason, high performance concrete can be designed by tailoring of beneficial effects [5, 6, 7]. However, primary requirement of this production is to disperse nano silica homogeneously into cementitious composites. In the opposite case, inhomogeneous particles can lead to voids and weak zones [8].

In last decade, numerous studies are undertaken by taking advantage of the nano silica, carbon nanotubes, nano titanium, nano alumina etc. Among nano products, nano-silica (SiO2) has been one of the most used nano material in advanced concrete studies since hydration mechanism of nano silica is still complex process and understanding of its mechanism is required to be focused on. Nowadays scientists study on the mechanical and durability properties of cementitious composites incorporating nano silica in order to enhance impermeability. Investigations comprise hydration kinetics of nano silica, micro structure healing, and fresh/hardened properties of cementitious composites.

The reason of producing high performance concrete with nano silica admixtures is reaction mechanism of cement hydration in the presence of nano silica. Cement hydration can be accelerated by nano silica admixture. In the case of nano-silica inclusion into cement particles, H2SiO4 occurs and react with Ca2+ so that additional C-S-H (calcium-silica-hydrate) which improves the strength and durability of concrete is formed. By this way, additional C-S-H products disperse in water and fill the spaces between cement particles. Additional products induce more compact C-S-H phases and seeding effect takes place in cement hydration. C-S-H phase not only takes place in cement particles but also acts in other voids thus many seeding products accelerate the early hydration of cement. In literature, acceleration of cement paste hydration and earlier occurrence of calcium hydroxide have been investigated extensively in many studies [9, 10, 11, 12, 13, 14]. In these studies, setting time of nano silica incorporated cement pastes is reduced and early hydration time is achieved as soon as possible in order to generate calcium hydroxide in shorter time. In similar studies, it was found that, in the presence of nano silica, C3S decomposed faster than normal cement hydration14. Micro analysis of these studies support the findings of abovementioned issues so far[15] (Figure 2).

It is known that nano-silica inclusion increase the C-S-H and C-A-H (calcium-alumina-hydrate) products in cement paste[16]. In addition to that, utilization of nano silica based activators triggers fly ash to assist more dense and less porous structure for composite production. For this reason, nano silica particles provide mineral admixture containing composites to perform better properties in an economic way [17]. Furthermore, nano silica additive contributes the thermal stability of cementitious material systems. For example, compared to silica fume incorporation into specimens, nano silica incorporated specimens have exhibited less strength loss at 500 C after the gradually increased temperatures [18]. It was also revealed that cement mixtures containing nano silica and
fly ash exhibited adequate strength performance up to 700 C and residual strength was not so different from the virgin ones. This is because after dehydration of C-S-H products, residual calcium silicate act as a new binder so that composite still perform its strength [19]. Nano silica incorporated composites have also low permeability characteristics and penetration of water is limited by nano silica presence. Therefore, healing of porous zones can be helpful to durable utilization of cementitious composites [20, 21, 22, 23, 24]. Studies mentioned at present can give point of view for the innovative research in civil engineering. Applications of nanotechnology have breakthrough potential in material technology. In the future, utilization of nano materials will contribute to many innovative materials owing to material design based on performance. As one of the most preferred nano product, importance of nano silica has been understood for a decade. In the light of mentioned issues, benefits of nano silica can be summarized as; enhancement of strength, blocking of porous structures, Acceleration of cement hydration and improvement of durability properties of concrete. Typical advantages of nano silica were also summarized in Figure 3.

It is obvious that, different properties of materials used in the investigations are the reason of this variability. Therefore, there is a necessity for novel method exhibiting the all functional improvements rather than mineral additive. Compared to other ingredients of concrete, additive of nano silica into concrete is more time-consuming. In addition to that there is a contradiction for each type of process that specify the optimum homogenous dispersion. Generally nano silica is added into mixtures by using sonication, homogenization or physical mixing process. Duration of this process, solution/nano silica ratio and variation of inclusions trigger different results since over mixing can change the texture of nano materials. In the same manner, shorter duration of mixing can lead to agglomeration of nano particles due to nano materials bonds. Beside these problems, usage of high range water reducer admixture can also have significant effect because of addition process [25]. It can be said that such details are not effective way to design cementitious composites in the real applications. For this reason novel, innovative and effective nano silica application is required to develop. One way of realizing this is to develop nano silica based solutions that can heal the cracks of cementitious composites or improve the durability and mechanical properties of composites. To practice it, the most effective curing solution and effective way of producing this method need to be studied. By this way significant savings of cement can be achieved and lifespan of structures can be extended. As it is mentioned in the earlier parts of this review, environmental problems of cement production can be limited by means of nano silica solution. The main purpose of this research should meet the strength loss of cementitious composites owing to superior pozzolonic reactivity of nano silica. Investigations that exploit the nanotechnology products can enable the designing of high performance concrete so that maintenance and rehabilitation cost of reinforced concrete buildings can be lowered. The main target of these studies need to address the following issues;

1) Observation of nano silica effect pervasively on the all surface of specimens
2) Determination of penetration tendency on the cementitious composites.
3) To specify the pozzolanic reactions to what extent in order to use these products for the enhancement of Durability properties.
4) Investigation of additional C-S-H on the virgin and damaged cementitious composites.

Novel findings are required to meet the summarized outputs as given in Figure 4.

C. Potential investigations and discussion

Utilization of nano silica is beneficial for improving the properties of cementitious composites. At the present time, no nanomaterial exists except nano silica that can improve both parameter, strength and durability for cementitious composites. However numerous studies exist that contradicts between themselves. Although contradictions for other ingredients ratio in the cementitious composites can be accepted, it is not the same for nano materials additives. In the conducted studies, it is normal to expect more accurate findings for nano silica material since economic aspect of nano materials is crucial. In this review, it can be said that ratio of nano silica in the use of cementitious composites has not been clearly determined in the surveyed studies.
Homogenously dispersion problem, variable results, high dosage of usage (%5-6 by weight of cement), high cost, increase of water demand at given workability are the drawbacks of nano silica utilization in the cementitious composites. Although nano silica additive has many advantages, abovementioned problems are needed to be resolved. 1 kg of micro silica correspond to 4 kg of cement in concrete mixtures. By taking advantage of nano silica more cement savings can be achieved. Cost of nano materials have decreased dramatically over decade however nano materials have still high cost compared to other ingredients of materials used in concrete. It is vital that functional nano silica applications should be improved by taking the account of cost parameter. Such investigations can assist to develop high amount of mineral admixture incorporated specimens by means of additional C-S-H so contribution to preservation of natural resources and energy efficient studies can also be realized.

It can be said that many researchers have studied the effects of nano silica on the cement paste or cement mortar although nano silica incorporated concrete investigations are less studied. Effects of nano silica on the absorption and mechanical properties of the cementitious composites are required to be focused on more extensively. Innovative studies can be beneficial especially for developing applicable and effective repairment material. Dispersion process and physical state of nano silica in concrete are still contradictory issues. Although dispersive agents are used in the process of dispersion, these kind of methods still leave questions marks over minds. The more innovative nano silica studies are conducted the easier and more effective applications can be achieved for civil engineering.

D. Conclusions

E. References


Comparison of Optical and Electrical Conductance and Refractive Index Values of the PTCDI-C5 Small Molecule for Various Relations and Conditions

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Abstract—The optical and electrical conductance of the PTCDI-C5 small molecule for different molarities and solvents were compared and the refractive index values of the PTCDI-C5 for various relations (experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar-Singh), different molarities, solvents and types of the optical band transitions were obtained. Effects of molarities and solvents on optical and electrical conductance of the PTCDI-C5 were investigated. Also, effects of various relations, molarities, solvents and types of the optical band transitions on refractive index of the PTCDI-C5 were investigated in detail. The refractive index values were controlled.

Keywords—Optical and electrical conductance, PTCDI-C5 small molecule, refractive index, molarity, solvent.

I. INTRODUCTION

Organic materials (OMs) such as organic polymers (OPs), organic conjugated polymers (OCPs), organic semiconductors (OSC) and organic nanomaterials (ONMs) have received substantial attention for many applications [1] such as diodes, solar cells (SCs), switches, displays, lasers, transistors, photovoltaics, sensors, generators, conversions, detectors [2-9]. To fabricate such devices, the fundamental properties of the materials are significant to determine suitable device or devices. OSCs such as N,N'-bis(2-((5-(dimethylamino)methyl)furan-2-yl)methylthio)ethyl) perylene-3,4,9,10-tetracarboxylic imide) PTCDI can be used in fabrication of the optoelectronic devices. PTCDIs have high photosensitivity, highly versatile molecules, high fluorescent quantum yield and low HOMO-positions [10].

Furthermore, many scientists made many researches on various materials for many applications. Lopez et al. [11] showed that the refractive index decreased with increasing flow ratio (Ro). Ali et al. [12] reported a Y_{0.225}Sn_{0.775}CoO_3 thin film for MgO (111) single crystal substrate with a dispersion energy value of 10.0 eV, a single-oscillator energy value of 3.76 eV, a M,1 moment value of 2.66 and a M,3 moment value of 0.19 eV⁻². Lalova and Todorov [13] varied the n value of the films from 1.78 to 2.42 at 1550 nm. Purniawan et al. [14] found the refractive index ratio (1.8) for ethanol and isopropyl alcohol (IPA). Manera et al. [15] reported that the refractive index (n) and reflectance values increased with increasing incident angle.

In this study, the aim is to compare the optical and electrical conductance of the PTCDI-C5 small molecule for different molarities and solvents and is to obtain the refractive index values of the PTCDI-C5 for various relations (experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar-Singh), different molarities, solvents and types of the optical band transitions.

II. EXPERIMENTAL DETAILS

PTCDI-C5 small molecule, chloroform, chlorobenzene and toluene solvents were used in this study (bought from Sigma–Aldrich Co.). The solutions of the PTCDI-C5 for different molarities and solvents were prepared. Then, the UV measurements for these materials were recorded.

II.A. THE SOLUTIONS FOR DIFFERENT MOLARITIES AND SOLVENTS

The molecular weight and formula of the PTCDI-C5 molecule are 530.61 g/mol and C_{30}H_{26}N_{2}O_{5} respectively. To prepare the solutions, The PTCDI-C5 material was weighed with a AND-GR-200 Series Analytical Balance (United States) for 6.618 and 0.654 mM molarities and for 0.436 mM of the chloroform, toluene and chlorobenzene solvents. After that, these PTCDI-C5 materials weighed for different molarities and solvents were dissolved homogeneously in related solvents.

II.B. THE UV MEASUREMENTS FOR DIFFERENT MOLARITIES AND SOLVENTS

The UV measurements for different molarities and solvents were performed by solution technique. For this, the cylindrical cuvettes (Hellma QS-100), whose optical path length and volume are 10 mm and 3.5 mL, respectively. The UV measurements of the PTCDI-C5 material for different molarities and solvents were recorded with a Shimadzu model UV-1800 Spectrophotometer at room temperature.

III. RESULTS AND DISCUSSION

III.A. COMPARISON OF OPTICAL AND ELECTRICAL CONDUCTANCE OF THE PTCDI-C5 FOR DIFFERENT MOLARITIES AND SOLVENTS
Conductance is an important parameter for optoelectronic devices. The optical conductance ($\sigma_{\text{op}}$) and electrical conductance ($\sigma_{\text{elec}}$) of the OMs can be obtained from [16],

$$\sigma_{\text{op}} = \frac{\alpha n c}{4\pi}$$

(1)

and

$$\sigma_{\text{elec}} = \frac{2\lambda\sigma_{\text{op}}}{\alpha}$$

(2)

where $\alpha$ is the absorption coefficient, $n$ is the refractive index, $c$ and $\lambda$ are the velocity and wavelength of light, respectively. The optical and electrical conductance values of the PTCDI-C5 molecule for different molarities and solvents were obtained from Eq. (1) and (2), respectively. Fig. 1(a,b) shows the $\sigma_{\text{op}}$ and $\sigma_{\text{elec}}$ plot vs. E of the PTCDI-C5 for 6.618 and 0.654 mM. As seen in Fig. 1(a,b), molarity has a significant effect on $\sigma_{\text{op}}$ and $\sigma_{\text{elec}}$ values of the PTCDI-C5. As seen in Fig. 1(a,b), the optical and electrical conductance of the PTCDI-C5 increase significantly with increasing molarity and the form of the $\sigma_{\text{op}}$ and $\sigma_{\text{elec}}$ curves varies due to high absorption coefficient with molarity. Also, the $\sigma_{\text{op}}$ values of the PTCDI-C5 for 6.618 and 0.654 mM are higher than the $\sigma_{\text{elec}}$ values of the PTCDI-C5 as seen in Fig. 1(a,b). These results indicate that the optical and electrical conductance of the PTCDI-C5 can be increased with increasing molarity and molarity affects the form of the optical and electrical conductance curves.

Fig. 2(a,b) indicates the $\sigma_{\text{op}}$ and $\sigma_{\text{elec}}$ plot vs. E of the PTCDI-C5 for chloroform, toluene and chlorobenzene solvents. As seen in Fig. 2(a,b), the forms of the $\sigma_{\text{op}}$ and $\sigma_{\text{elec}}$ curves of the PTCDI-C5 are close to each other, but the average $\sigma_{\text{op}}$ and $\sigma_{\text{elec}}$ values for toluene are the highest. As seen in Fig. 2(a,b), the $\sigma_{\text{op}}$ and $\sigma_{\text{elec}}$ of the PTCDI-C5 exhibit the maximum peaks between about 2.3 and 2.65 eV. The $\sigma_{\text{op}}$ values of the PTCDI-C5 for chloroform, toluene and chlorobenzene solvents are higher than the $\sigma_{\text{elec}}$ values of the PTCDI-C5 as seen in Fig. 2(a,b). Obtained results show that for higher optical and electrical conductance values of the PTCDI-C5, toluene can be preferred according to chloroform and chlorobenzene solvents and the optical and electrical conductance can be varied with solvents.

![Optical Conductance and Electrical Conductance](image)

**Fig. 1.** The (a) optical conductance ($\sigma_{\text{op}}$) and (b) electrical conductance ($\sigma_{\text{elec}}$) plot vs. E of the PTCDI-C5 for 6.618 and 0.654 mM.

![Optical Conductance and Electrical Conductance](image)

**Fig. 2.** The (a) optical conductance ($\sigma_{\text{op}}$) and (b) electrical conductance ($\sigma_{\text{elec}}$) plot vs. E of the PTCDI-C5 for chloroform, toluene and chlorobenzene solvents.

### III.B. REFRACTIVE INDEX VALUES OF THE PTCDI-C5 FOR VARIOUS RELATIONS, DIFFERENT MOLARITIES, SOLVENTS AND TYPES OF THE OPTICAL BAND TRANSITIONS

The refractive index ($n$) is an important parameter for optoelectronic applications and technologies. The $n$ is known to decrease with energy gap. The $n$ can be calculated by [17,18],

$$n = \left[ \frac{4R}{(R-1)^2 - k^2} \right]^{1/2} - \frac{R+1}{R-1}$$

(3)
The n values of the PTCDI-C5 molecule for different molarities and solvents were calculated from Eq. (3). Obtained n values are given in Tables I(a) and II(a), respectively. As seen in Table I(a), the n value (3.118) of the PTCDI-C5 for 0.654 mM is lower than the n value (3.337) of the PTCDI-C5 for 6.618 mM. As seen in Table II(a), the n value (3.096) of the PTCDI-C5 for chloroform solvent is the lowest, while the n value (3.129) of the PTCDI-C5 for toluene solvent is the highest. Obtained results suggest that the refractive index of the PTCDI-C5 can be increased with increasing molarity and can be controlled by solvents.

There are many relations such as experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar-Singh between the energy gap and refractive index of semiconductors [19] and these relations are extensively used to determine the refractive index. In our previous study [1], we obtained the direct ($E_{gd}$) and indirect optical band gap ($E_{g}$) values of the PTCDI-C5 semiconductor for 6.618 and 0.654 mM. These $E_{gd}$ and $E_{g}$ values are as given in Table I(a,b). Similarly, in our another previous study [10], we obtained the $E_{gd}$ and $E_{g}$ values of the PTCDI-C5 semiconductor for chloroform, toluene and chlorobenzene solvents. These $E_{gd}$ and $E_{g}$ values are as seen in Table II(a,b).

Moss relation is given by

$$n = \left( \frac{95 \text{eV}}{E_g} \right)^{1/4}$$

(4)

For different molarities and Moss relation, the n values of the PTCDI-C5 molecule at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (4) and are given in Table I(a,b). As seen in Table I(a,b), the n values (2.537 and 2.557, respectively) for 0.654 and 6.618 mM at the $E_{gd}$ values are lower than the n values (2.547 and 2.584, respectively) for 0.654 and 6.618 mM at the $E_{g}$ values. Similarly, for different solvents and Moss relation, the n values of the PTCDI-C5 molecule at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (4) and are given in Table II(a,b). As seen in Table II(a,b), the n values (2.542, 2.565 and 2.545, respectively) for chloroform, toluene and chlorobenzene solvents at the $E_{gd}$ values are lower than the n values (2.555, 2.578 and 2.562, respectively) at the $E_{g}$ values.

Ravindra relation is given by

$$n = 4.084 - 0.62E_g$$

(5)

For different molarities and Ravindra relation, the n values of the PTCDI-C5 molecule at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (5) and are given in Table I(a,b). As seen in Table I(a,b), the n values (2.663 and 2.707, respectively) for 0.654 and 6.618 mM at the $E_{gd}$ values are lower than the n values (2.685 and 2.763, respectively) for 0.654 and 6.618 mM at the $E_{g}$ values. Similarly, for different solvents and Ravindra relation, the n values of the PTCDI-C5 at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (5) and are given in Table II(a,b). As seen in Table II(a,b), the n values (2.672, 2.724 and 2.681, respectively) for chloroform, toluene and chlorobenzene solvents at the $E_{gd}$ values are lower than the n values (2.702, 2.750 and 2.718, respectively) at the $E_{g}$ values.

Herve-Vandamme relation is given by

$$n = \left( 1 + \frac{4}{E_{gd}B} \right)^{1/2}$$

(6)

where A is the hydrogen ionization energy 13.6 eV and B = 3.47 eV is a constant assumed to be the difference between the band gap energy and UV resonance energy. For different molarities and Herve-Vandamme relation, the n values of the PTCDI-C5 molecule at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (6) and are given in Table I(a,b). As seen in Table I(a,b), the n values (2.563 and 2.591, respectively) for 0.654 and 6.618 mM at the $E_{gd}$ values are lower than the n values (2.577 and 2.626, respectively) for 0.654 and 6.618 mM at the $E_{g}$ values. Similarly, for different solvents and Herve-Vandamme relation, the n values of the PTCDI-C5 at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (6) and are given in Table II(a,b). As seen in Table II(a,b), the n values (2.569, 2.601 and 2.574, respectively) for chloroform, toluene and chlorobenzene solvents at the $E_{gd}$ values are lower than the n values (2.587, 2.618 and 2.597, respectively) at the $E_{g}$ values.

Reddy relation is given by

$$n = \left( \frac{154}{(E_{gd}-0.365)} \right)^{1/4}$$

(7)

For different molarities and Reddy relation, the n values of the PTCDI-C5 molecule at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (7) and are given in Table I(a,b). As seen in Table I(a,b), the n values (2.990 and 3.018, respectively) for 0.654 and 6.618 mM at the $E_{gd}$ values are lower than the n values (3.004 and 3.056, respectively) for 0.654 and 6.618 mM at the $E_{g}$ values. Similarly, for different solvents and Reddy relation, the n values of the PTCDI-C5 at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (7) and are given in Table II(a,b). As seen in Table II(a,b), the n values (2.996, 3.029 and 3.001, respectively) for chloroform, toluene and chlorobenzene solvents at the $E_{gd}$ values are lower than the n values (3.015, 3.047 and 3.025, respectively) at the $E_{g}$ values.

Kumar-Singh relation is given by

$$n = 3.366E_{gd}^{-0.32234}$$

(8)

For different molarities and Kumar-Singh relation, the n values of the PTCDI-C5 molecule at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (8) and are given in Table I(a,b). As seen in Table I(a,b), the n values (2.577 and 2.603, respectively) for 0.654 and 6.618 mM at the $E_{gd}$ values are lower than the n values (2.590 and 2.639, respectively) for 0.654 and 6.618 mM at the $E_{g}$ values. Similarly, for different solvents and Kumar-Singh relation, the n values of the PTCDI-C5 at the related $E_{gd}$ and $E_{g}$ values were obtained from Eq. (8) and are given in Table II(a,b). As seen in Table II(a,b), the n values (2.582, 2.614 and 2.588, respectively) for chloroform, toluene and chlorobenzene solvents at the $E_{gd}$ values are lower than the n values (2.600, 2.630 and 2.610, respectively) at the $E_{g}$ values. These results indicate that the refractive index for experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar and Singh relations increases with increasing molarity and the n values of the $E_{gd}$ are higher than the n values of the $E_{g}$ values. Also, the refractive index for experimental, Moss, Ravindra, Herve-Vandamme, Reddy
and Kumar and Singh relations can be controlled with various solvents.

Table I. The optical parameters of the PTCDI-C5 small molecule for 0.654 and 6.618 mM molarities at (a) direct optical band gap (E_{gd}) and (b) indirect optical band gap (E_{gid}) values.

<table>
<thead>
<tr>
<th>Solvents</th>
<th>E_{gd} (eV)</th>
<th>Refractive index values obtained from various relations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(mM)</td>
<td>Exp</td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.654</td>
<td>2.292</td>
</tr>
<tr>
<td></td>
<td>6.618</td>
<td>2.221</td>
</tr>
</tbody>
</table>

(b)

Table II. The optical parameters of the PTCDI-C5 small molecule for chloroform, toluene and chlorobenzene solvents at (a) direct optical band gap (E_{gd}) and (b) indirect optical band gap (E_{gid}) values.

<table>
<thead>
<tr>
<th>Solvents</th>
<th>E_{gd} (eV)</th>
<th>Refractive index values obtained from various relations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(mM)</td>
<td>Exp</td>
</tr>
<tr>
<td>Chloroform</td>
<td>0.654</td>
<td>2.216</td>
</tr>
<tr>
<td></td>
<td>6.618</td>
<td>2.113</td>
</tr>
</tbody>
</table>

Thus, the refractive index values of the PTCDI-C5 for different molarities at the related E_{gd} and E_{gid} values were obtained from experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar and Singh relations (see Fig. 3(a,b)). Similarly, the refractive index values of the PTCDI-C5 for different solvents at the related E_{gd} and E_{gid} values were obtained from experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar and Singh relations (see Fig. 4(a,b)). As seen in Figs. 3(a,b) and 4(a,b), the refractive index values obtained from experimental data are the highest, while the refractive index values obtained from Moss relation are the lowest.

Fig. 3. The refractive index values of the PTCDI-C5 obtained from various relations for different molarities at the related (a) E_{gd} and (b) E_{gid} values.

Fig. 4. The refractive index values of the PTCDI-C5 for different solvents obtained from various relations at the related (a) E_{gd} and (b) E_{gid} values.

IV. CONCLUSIONS

The optical and electrical conductance of the PTCDI-C5 semiconductor for different molarities and solvents were compared. Then, the refractive index values of the PTCDI-C5 for various relations, different molarities, solvents and types of the optical band transitions were obtained. The optical/electrical conductance and refractive index values of the PTCDI-C5 increase with increasing molarity. For higher optical and electrical conductance values of the PTCDI-C5, toluene can be preferred according to chloroform and chlorobenzene solvents. The refractive index (n) for
experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar and Singh relations increases with increasing molarity and the n values of the indirect optical band gap ($E_{\text{gid}}$) are higher than the n values of the direct optical band gap ($E_{\text{gd}}$) values. Also, the refractive index for experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar and Singh relations can be controlled with various solvents. The refractive index values obtained from experimental data are the highest, while the refractive index values obtained from Moss relation are the lowest.

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REFERENCES

Analysis of Refractive Index Dispersion and Relation between Optical Band Gaps and Indexes of Refraction of PPTTPP Nanofiber

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Abstract—The refractive index dispersion of the PPTTPP crystal nanofiber for different solvents was analyzed. The relation between optical band gaps and indexes of refraction of PPTTPP crystal nanofiber for different solvents was investigated. Effects of solvents on refractive index dispersion and indexes of refraction were investigated in detail. Finally, the surface morphology properties of the PPTTPP film were investigated by a Park System, XE100 atomic force microscope (AFM).

Keywords—Refractive index dispersion, PPTTPP crystal nanofiber, refractive index, solvents, AFM.

I. INTRODUCTION

Organic single crystal materials (OSCMs) have many advantages such as their lower cost, high chemical purity, high order molecular packing, excellent optoelectronic properties and easier processability [1-4]. OSCMs are widely used in the photonic and optoelectronic devices such as transistors, cells, electroluminescence (EL) devices, diodes and lasers[2,3]. 5,5′-di-4-biphenyl-2,2′-bithiophene (PPTTPP) crystal nanofiber, which is organic fluorescence material is known as BP2T [5]. The fundamental properties of the PPTTPP crystal nanofiber are significant for materials science, organic materials, p-type small molecules, printed electronics and p-type organic semiconductors.

The aim of this study is to analyze the refractive index dispersion of the PPTTPP crystal nanofiber for different solvents and is to investigate the relation between optical band gaps and indexes of refraction of PPTTPP crystal nanofiber for different solvents. The optical measurements were conducted on a Shimadzu model UV-1800 Spectrophotometer at room temperature. Finally, the surface morphology properties of the PPTTPP film were investigated by a Park System, XE100 atomic force microscope (AFM).

II. EXPERIMENTAL

5,5′-Di(4-biphenyl)-2,2′-bithiophene (PPTTPP) nanofiber (Sigma–Aldrich), N,N-dimethylformamide (DMF), chloroform, and toluene solvents (Merck Co.) were used in this study.

II.A. THE SOLUTIONS OF THE PPTTPP NANOFIBER FOR DIFFERENT SOLVENTS

The molecular formula and weight of the PPTTPP are C_{32}H_{22}S_{2} and 470.65 g/mol, respectively. The PPTTPP materials were weighed to prepare the solutions with a AND-GR-200 Series Analytical Balance for 0.611 mM and were dissolved homogeneously in 10 mL volume of DMF, chloroform and toluene solvents. To obtain the best results of the optical measurements, the prepared solutions of the PPTTPP were filtered through PTFE membrane filter.

II.B. THE OPTICAL MEASUREMENTS

The optical measurements of the PPTTPP crystal nanofiber for different solvents were performed by solution technique. For this, we used the cylindrical cuvettes (Hellma QS-100), which have 10 mm optical path length and 3.5 mL volume. The optical measurements of the solutions of the PPTTPP for different solvents were taken by a Shimadzu model UV-1800 Spectrophotometer at room temperature.

II.C. PPTTPP NANOFIBER FILM

The prepared and filtered solution of the PPTTPP nanofiber was deposited on cleaned microscopy glass at 3000 rpm for 20 s by the spin coating method. After that, the film was dried at 60 °C for 5 min to remove organic residuals and evaporate the solvent. Surface morphology properties of the PPTTPP film were investigated by a Park System, XE100 atomic force microscope (AFM).

III. RESULTS AND DISCUSSION

III.A. ANALYSIS OF REFRACTIVE INDEX DISPERSION OF THE PPTTPP CRYSTAL NANOFIBER

The refractive index (n) is an important parameter for photonic and optoelectronic applications. The n can be calculated by [6,7],

\[ n = \left( \frac{4R}{(R-1)^2-k^2} \right)^{1/2} \frac{R+1}{R-1} \]  

The n values of the PPTTPP crystal nanofiber for DMF, chloroform and toluene solvents were obtained from Eq. (1). Fig. 1 shows the plot of n vs. \( \lambda \) of the PPTTPP nanofiber for DMF, chloroform and toluene solvents. As seen in Fig. 1, the refractive index values of the PPTTPP for toluene solvent are the highest, while the refractive index values of the PPTTPP for DMF solvent are the lowest. This result suggests that the refractive index of the PPTTPP crystal nanofiber can be varied by various solvents and solvents play a significant role on refractive index of the PPTTPP nanofiber.
The given in Table I. As seen in Table I, the \( E_0 \) values of the PPTTPP nanofiber for DMF, chloroform and toluene solvents were obtained from [11]:
\[
E_0' = \frac{M_1}{M_3}
\]
and
\[
E_3' = \frac{M_1'}{M_3'}
\]
The \( M_1 \) and \( M_3 \) moments of the PPTTPP nanofiber for DMF, chloroform and toluene solvents were found and given in Table I. As seen in Table I, the \( M_1 \) value varies from 2.249 to 5.688 and the \( M_3 \) value shifts from 0.945 to 2.194 eV\(^2\) with changing solvent.

The optical oscillator strength \( f \) is an important parameter and it is given the following equation [10]:
\[
f = \frac{E_0E_d}{E_0 + E_3'}
\]
The optical oscillator strength of the PPTTPP nanofiber for DMF, chloroform and toluene solvents were obtained and given in Table I. As seen in Table I, the \( f \) value shifts from 5.352 to 14.743 eV\(^2\). This result suggests that the optical oscillator strength can be varied with various solvents.

### Table II. \( \sigma \) single oscillator model parameters of the PPTTPP nanofiber for DMF, chloroform and toluene solvents.

<table>
<thead>
<tr>
<th>Solvents</th>
<th>( E_0 ) (eV)</th>
<th>( E_3' ) (eV)</th>
<th>( M_1 )</th>
<th>( M_3 ) (eV(^2))</th>
<th>( f ) (eV(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloroform</td>
<td>1.604</td>
<td>5.575</td>
<td>5.476</td>
<td>1.352</td>
<td>8.941</td>
</tr>
<tr>
<td>DMF</td>
<td>1.543</td>
<td>3.470</td>
<td>2.249</td>
<td>0.945</td>
<td>5.352</td>
</tr>
<tr>
<td>Toluene</td>
<td>1.610</td>
<td>9.157</td>
<td>5.688</td>
<td>2.194</td>
<td>14.743</td>
</tr>
</tbody>
</table>

#### III.B. RELATION BETWEEN OPTICAL BAND GAPS AND INDEXES OF REFRACTION OF PPTTPP CRYSTAL NANOFIBER

The \( \sigma \) values of the PPTTPP nanofiber for DMF, chloroform and toluene solvents were calculated from Eq. (1). Obtained \( \sigma \) values are given in Tables II. As seen in Table II, the \( \sigma \) value (2.558) of the PPTTPP for DMF solvent is the lowest, while the \( \sigma \) value (2.627) of the PPTTPP for toluene solvent is the highest. Obtained results suggest that the refractive index of the PPTTPP can be controlled by solvents.

There are many relations such as experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar-Singh between the energy gap and refractive index of semiconductors [9]. In our previous study [4], we obtained the optical band gap \( E_g \) values of the PPTTPP nanofiber for DMF, chloroform and toluene solvents. These \( E_g \) values are also given in Table II.

Moss relation is given by
\[
\sigma = \left( \frac{95 eV}{E_g} \right)^{1/4}
\]
For different solvents and Moss relation, the \( \sigma \) values of the PPTTPP were obtained from Eq. (6) and are given in Table II. As seen in Table II, the \( \sigma \) value (2.575) of the PPTTPP for DMF solvent and Moss relation is the lowest, while the \( \sigma \) value (2.629) of the PPTTPP for toluene solvent is the highest.

Ravindra relation is given by
\[
\sigma = 4.084 - 0.62E_g
\]
For different solvents and Ravindra relation, the n values of the PPTTPP were obtained from Eq. (7) and are given in Table II. As seen in Table II, the n value (2.744) of the PPTTPP for DMF solvent and Ravindra relation is the lowest, while the n value (2.851) of the PPTTPP for toluene solvent is the highest.

Herve-Vandamme relation is given by

\[ n = \left( 1 + \left( \frac{A}{E_g + B} \right)^2 \right)^{1/2} \]  

\[ (8) \]

where A is the hydrogen ionization energy 13.6 eV and B = 3.47 eV is a constant assumed to be the difference between the band gap energy and UV resonance energy. For different solvents and Herve-Vandamme relation, the n values of the PPTTPP were obtained from Eq. (8) and are given in Table II. As seen in Table II, the n value (2.614) of the PPTTPP for DMF solvent and Herve-Vandamme relation is the lowest, while the n value (2.685) of the PPTTPP for toluene solvent is the highest.

Reddy relation is given by

\[ n = \left( 1 + \left( \frac{A}{E_g - 0.365} \right)^2 \right)^{1/4} \]  

\[ (9) \]

For different solvents and Reddy relation, the n values of the PPTTPP were obtained from Eq. (9) and are given in Table II. As seen in Table II, the n value (3.043) of the PPTTPP for DMF solvent and Reddy relation is the lowest, while the n value (3.121) of the PPTTPP for toluene solvent is the highest.

Kumar-Singh relation is given by

\[ n = 3.3668(E_g - 0.3223)^{-0.3223} \]  

\[ (10) \]

For different solvents and Kumar-Singh relation, the n values of the PPTTPP were obtained from Eq. (10) and are given in Table II. As seen in Table II, the n value (2.626) of the PPTTPP for DMF solvent and Kumar-Singh relation is the lowest, while the n value (2.698) of the PPTTPP for toluene solvent is the highest. These results indicate that the refractive index for experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar and Singh relations can be controlled with various solvents and the highest refractive index values of the PPTTPP can be obtained with toluene solvent.

**Table II.** The optical parameters of the PPTTPP nanofiber for DMF, chloroform and toluene solvents.

<table>
<thead>
<tr>
<th>Solvents</th>
<th>E_g (eV) [4]</th>
<th>Refractive index values obtained from various relations</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMF</td>
<td>2.161</td>
<td>2.158</td>
</tr>
<tr>
<td>Toluene</td>
<td>1.989</td>
<td>2.627</td>
</tr>
</tbody>
</table>

Thus, the refractive index values of the PPTTPP nanofiber for DMF, chloroform and toluene solvents were obtained from experimental, Moss, Ravindra, Herve-Vandamme, Reddy and Kumar and Singh relations as seen in Fig. 3. As seen in Fig. 3, the refractive index values obtained from Reddy relation are the highest, while the refractive index values obtained from experimental data are the lowest.

**III.C. Surface morphology properties of the PPTTPP film**

The surface morphology properties of the PPTTPP nanofiber film deposited on cleaned microscopy glass were investigated using an AFM. The scan area was chosen as 10x10 µm². Fig. 4 indicates one (1D) topography image of the PPTTPP film. As seen in Fig. 4, PPTTPP film consists of different crystal grains, which are different shapes and sizes.

**Fig. 3.** The refractive index values of the PPTTPP nanofiber obtained from various relations for DMF, chloroform and toluene solvents.

**Fig. 4** The one (1D) topography image of the PPTTPP film.

**ACKNOWLEDGMENT**

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Analyzing the Eutectic Al-Si Alloys Modification Using Al10Sr and CuSn5 Master Alloys

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Abstract—Changing the size and distribution of the eutectic silisium particles by the addition of alkali metals such as Na, Sr, K, Rb, Cs, Li, Ca, Ba, Mg, La, P, Bi, Cd, Mn, Ni, Pb to Al-Si alloy is called modification. Modification process can be done in different ways such as the addition of elements, rapid solidification, vibration applied during solidification, high pressure and spheroidizing by heat treatment. The modification of casting structure can be described as to be converted from lamellar eutectic Si structure to fiberims structure. During modification process the growth of silicon crystals slows down in the eutectic, the growth of silica-matrix is stabilized and fine lamellar structure is formed in this way. The most practical and widespread application for the modified process is the modification process by the addition of element and the most effective modification can be made by using Na, Sr and Sb. However, there are only strong implications using Na and Sr for industrial applications in a low concentration. Percent elongation and castability of strontium-modified alloy are higher than those modified with sodium. Also the initial effect of Na and Sr is very good, due to the loosening of oxidation and vapor pressure for sodium this effect is temporary. Alternatively, when processing features of Al-Si alloy with eutectoid composition is important it is known to supply significant advantages for the modification with CuSn5 alloys. In this study to examine the effect of the modification of eutectic Al-Si alloy casting experiments will be done. Casting experiments will be done in four ways by no addition, adding Al10Sr, adding CuSn5 and adding Al10Sr+CuSn5 master alloy. The microstructures of the cast samples will be analyzed and the effect of the modification will be determined depending on the master alloy.

Keywords—Aluminum Casting, Modification, Eutectic Solidification, Al10Sr, CuSn5.

I. INTRODUCTION

Aluminum-silicon alloys are used in the casting of automotive parts and in aerospace applications due to their mechanical properties, light weight, high thermal conductivity and low thermal expansion. They have also high viscosity during casting due to containing high amount silicon. Therefore it is necessary to continuously improve the quality of the castings made from these alloys and mechanical properties [1]. Mechanical properties are affected by the microstructure. Al-Si alloys have ductile aluminium phase and hard and brittle silicon phase which is needle shape [1, 2].

Eutectic modification is a process in which mechanical properties, especially strain and ductility, are developed by modifying of eutectic silicon phase in Al-Si eutectic alloys [3]. The process is carried out adding the alkaline elements such as Na, Sr, K, Rb, Cs, Li, Ca, Ba, Mg, La, P, Bi, Cd, Mn, Ni, Pb. The modification also can be achieved by heat treatment, rapid solidification and high pressure effects. Aim of this process is to transform from lamellar eutectic Si phase to fiber structure [4-7]. Adding of Na, Sr and Sb is the most effective method for the modification [4,6]. The microstructure modified with Sr and Sb is given in Figure 1.

Fig 1. The microstructure photographs of Al-Si eutectic alloy a) unmodified, b) modified with Sr and c) modified with Sb [8].

However, there are strong effects of Na and Sr in the industrial application [6-8]. The initial effects of Na and Sr are strong. However, the effects of Na is temporary due to oxidation [6]. In the literature, there are a lot of study about modified Al12Si [9-16]. While some of them is related to the microstructure, another is on mechanical properties.
In this study, the microstructure and mechanical properties of eutectic Al-Si alloy modified with CuSn5, Al10Sr, CuSn5+Al10Sr and unmodified alloy were investigated. Microstructure and chemical analyses and hardness measurement were carried out to characterization of the alloys. According to the experimental results, effects of alloying elements and modification are determined.

II. EXPERIMENTAL STUDIES

In this study, Al12Si master alloys with different modifications were investigated. Al12Si alloy was used as master alloy containing 12%Si. Al10Sr and CuSn5 master alloys were used as modifying alloys to determine effect of the alloys. The chemical composition of the alloys used in the study can be seen in Table 1.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>CHEMICAL COMPOSITION OF THE ALLOYS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Si</td>
</tr>
<tr>
<td>Majority</td>
<td>78</td>
</tr>
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<td>Majority</td>
<td>78</td>
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<td>Majority</td>
<td>78</td>
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<tr>
<td>Majority</td>
<td>78</td>
</tr>
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</table>

The alloys were melted by electric resistance furnace in SiC curicible. For all of the test parameters, sufficient amount of aluminum ingot was placed in the furnace and the temperature increased to 700°C. After melting was completed, degassing and deslagging were done. Then the molten was poured into permanent mould in which temperature was 150°C, shown in Figure 2. The test samples were removed from the permanent mould after solidification and cooling and obtained 20 mm in diameter and 100 mm in height.

The samples for microstructural analysis were initially polished with 80, 400, 600, 800 and 1000 grit SiC emery papers and finally were polished with 1 μm diamond paste. Microstructural examination of all samples was performed by using a Nikon MA 100 Eclipse optical microscope. Hardness measurement was carried out under 10 kg preload and 60 kg major load with steel ball in 3.175 mm diameter.

III. EXPERIMENTAL RESULTS

Figure 3 shows the microstructure of the unmodified Al12Si, Al12Si+CuSn5, Al12Si+Al10Sr and Al12Si+Al10Sr+CuSn5 alloys after casting. The unmodified Al12Si eutectic alloy has Si phases which are needle, long and coarse shape. Unmodified eutectic Si alloys have generally coarse grains and when compared modified Al12Si alloys, the needle and coarse structure cause to decrease tensile strength and ductility [5, 11].

CuSn5 alloy has finer Si phases. Therefore, it can be said that copper affects to the microstructure and causes to increase the hardness. When copper and phosphor are added to Al-Si alloys, AlP forms and lamellar grains transform to block form [15]. In this work, it was observed that lamellar structure formed in Si phases and increased the hardness.

Uludag et al. [17] reported that in the alloys with Sr, when cooling rate increased primary Si phases become smaller and secondary Si phases become smaller as well and partially segregate. When Al10Sr alloy analyzed that strontium caused to be the finest fibrous structure in all alloys. Effect of Sr modifier on hardness having very little was observed. Strontium as a modifier in Al-Si eutectic alloys, morphology of eutectic transforms from coarse and needle structure to the fibrous structure, which leads to good mechanical properties [18].

When Al10Sr+CuSn5 master alloy was investigated it was observed that the morphology of Si phases changed to fibrous structure from coarse needle compared to the unmodified alloy. The morphology transformation leads to increase on hardness. Also, in Al10Sr+CuSn5 master alloy, Si phases coarser than that of Al10Sr master alloy due to decreasing of modification effect. Therefore in modification process, the metals having least phosphorus are used [19].

Figure 4 shows hardness results of the alloys. The unmodified Al12Si alloy has the lowest hardness. Tasha et al. [20] reported that copper and magnesium increase the hardness and surface quality. The alloy modified with CuSn5 has better hardness compared to the unmodified alloy and the alloy modified with Sr due to effect of copper on mechanical properties. Copper increases yield and tensile strength and hardness via precipitation hardening [2]. The alloy modified with Al10Sr has higher hardness to the unmodified alloy. However, the alloy modified with CuSn5 has higher hardness than the alloy modified with Al10Sr. Therefore it can be said that CuSn5 master alloy increase the mechanical properties to Al10Sr. Strontium modifies the microstructure of aluminium silicon eutectic rather than to improve the mechanical properties. The best amount of modification elements is between 0.008% and 0.04% [5].

Barzani et al. [21] reported that antimony and strontium affect only hard Si phase. When Al10Sr and CuSn5 master alloys added the Al12Si alloy, the highest hardness values were obtained. It was also observed that, Al10Sr + CuSn5
master alloy has more effect to improve the mechanical properties to the Al10Sr alloy.

### IV. CONCLUSIONS

In this study, Al12Si alloy was modified with Al10Sr, CuSn5 and Al10Sr+CuSn5 master alloys. The results obtained in studies are given in summary below:

- It was obtained that Si phases are lamellar, long and coarse morphology in main Al12Si alloy whereas lamellar structure is finer morphology in CuSn5 master alloy. When Al10Sr and CuSn5 master alloys are used together, Si phases change to fiberous structure from lamellar. In Al10Sr master alloy, strontium is more effective in grain refinement.
- According to the positive changes in the microstructure of the master alloys, it was observed that modification effect can be ranged such as Al10Sr, Al10Sr+CuSn5, CuSn5.
- The highest hardness was obtained in the Al10Sr + CuSn5 master alloy. Also in the other alloys, hardness values are almost same.
Al10Sr master alloy has strong modification effect on the microstructure rather than hardness. However, CuSn5 master alloy increased the hardness rather than modification the microstructure.

REFERENCES


Detection and Counting of Embryonic Stem Cells in Fluorescence Microscopy Images by a Fully Automatic Method

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Abstract—In this paper, an automatic cell counting method under microscopy is proposed. The cell counting process can be performed in two ways: The manual counting in which a specialist counts the cells with naked eye, and the automatic counting that utilizes the computer-based techniques. In manual counting, there are several techniques for dying the cells to turn them visible with naked eye. However, if the concentration is more than normal the cells can overlap. Overlap and incorrect adjusted microscopy parameters are the main factors that cause inaccurate counting results. Furthermore, in manual counting inter-observer variability is high. Even though the same cell image is taken into account by the different specialist, different counting results can be obtained. Because of the above mentioned problems, the cell counting process must be performed automatically.

The proposed automatic stem cell counting process is based on image processing techniques that appropriate the frame of method. At first, stem cell sections were obtained under the fluorescence microscopy. In the following pre-processing step Gaussian filtering and background extraction are performed. Before applying watershed algorithm histogram of the image is partitioned in to four parts and the best combination is determined to obtain the most exact counting results. The aim of using watershed algorithm is to make the boundaries and maximum points of the cells more clear. Finally, spherical contours corresponding to the stem cells are counted.

The effectiveness of the proposed method is evaluated by performing numerous computer simulations. It is shown that the proposed method gives promising results and can eliminate the subjectivity originated from the manual counting. The method is tested on a database contains two image groups at different noise levels validated by the specialists.

Keywords—cell counting, cell detection, pre-processing, embryonic stem cell, watershed algorithm.

I. INTRODUCTION

In recent years, cell researchers are interested in counting, sorting and tracking the cells. The specialists at clinics and hospitals use cell counting in determining the health condition of a patient. Cell counting is a valuable process used for different investigations. For example, in molecular biology and biochemistry, finding the concentration of cells is important during some experiments. This value is essential for calculating the volume of a particular chemical substance or reagent that should be applied to the concentration of cells in order to obtain reliable results. Cell counting is also used in measuring cell viability. This is the calculation of the number of dead and living cells in a cell culture and useful for determining the life expectancy of a cancerous cell, the effectiveness of insecticides and pesticides or the environmental harmfulness of poisons and toxins.

Stem cells have a special importance in clinical researches and they provide a promising cell source especially for developing new diagnosis and treatment techniques. Stem cells can turn into many different cell types in the body during early life and growth. They can serve as a sort of internal repair system, dividing essentially without limit to replenish other cells as long as the person is still alive. Stem cell research is still one of the most challenging areas in biology.

Embryonic stem cells (ESC) are denominated as “super cells” with their self-renewing elements and properties of generating all endoderm, ectoderm and mesoderm layers. ESC are derived from human pre-implantation embryos. Their differentiation process can be managed by culturing them in non-adherent plates. Counting ESC is an important task that has numerous applications afterwards [1, 2].

There are a lot of ways to count human cells. Medical research has found various methodologies that does not only count the cells but also determine other aspects such as cell shape and other properties. Todays, with the advent of dreadful diseases such as tumors, cancers, and other deadly diseases, cell counting has become even more important in the field of medicine and science. Through this medical procedure, cancer cells and other harmful diseases can be determined and treated accordingly. The cell counting process can be performed in two ways: The manual counting in which a specialist counts the cells with naked eye, and the automatic counting that utilizes the computer-based techniques. In manual counting, there are several techniques for dying the cells to turn them visible with naked eye. However, if the concentration is more than normal the cells can overlap. Overlap and incorrect adjusted microscopy parameters are the main factors that cause inaccurate counting results. Furthermore, in manual counting inter-observer variability is high. Even though the same cell image is taken into account.
by the different specialist, different counting results can be obtained. Because of the above mentioned problems, the cell counting process must be performed automatically. There exist various studies in the literature applying different image processing algorithms to the cell image [3-10]. Advanced digital image processing methods and pattern recognition techniques are used in various applications, too [11-13].

In this study we propose an automatic ESC detection and counting method for fluorescence microscopy images based on commonly used image processing techniques. In the pre-processing red-green-blue (RGB) channel image split in to the individual R, G and B channels, respectively. Next, Gaussian filtering and background extraction have been performed for green channel which gives the best counting results according to the experiments. Before applying watershed algorithm, the histogram of pre-processed image is calculated. Then, histogram of the image is partitioned into four equal intervals and best combination of these intervals is determined with various trials. By using watershed algorithm, we separate the overlapped cells from each other. Finally, spherical contours corresponding to the stem cells are counted.

The study is organized as follows: in Section II, the pre-processing step including background extraction and filtering is discussed. In Section III, watershed algorithm for cell counting is explained. Experimental results and comparisons are given in Section IV. Finally, Section V concludes the paper.

II. PRE-PROCESSING STEP

In this section, pre-processing step including background extraction and filtering is explained. Because of the distortions in cell images, this step is necessary before counting the cells. For this study, embryoid bodies’ images are given by Geisa Martins Faustino. Database contains 92 different cell images. Acquisition of cell images is described in reference [2]. In Figure 1, captured images distorted by low noise and high noise are illustrated as an example.

The necessity of applying pre-processing step arises from the following reasons. At first, it is important to adjust the focus of microscope properly. Wrong adjusted microscopy parameters cause wrong counting results. At this case manual counting with naked eye is becomes impossible. Second, to make cells more visible in microscopy images there are various dying techniques. The concentration level of dying is crucial. For example, if the concentration is high cell overlap occurs. Overlap is one of the main reasons of erroneous counting results. At last, the presence of fluorescence image noise may also cause the inaccurate counting.

In conclusion, the pre-processing step is needed to make cell images more clear and convenient for counting. Now, we describe the procedures, respectively.

A. Filtering

When the cell images are taken with fluorescence microscope, the luminance of pixel in the center of cell is lighter than the boundaries of the cell. By exploiting this property, cell counting with maximum brightness analysis becomes possible. In this study, the Gaussian blur filter is used to smooth the surface and put forward the maximum points of cell images. In Figure 2, surface of a cell image before and after Gaussian filtering is illustrated.

From the figure, we can say that using Gaussian filter makes the maximum points of the image more explicit than normal.

B. Background Extraction

Segmentation is one of the influential process in digital image analysis. It is known that, the performance of the segmentation turns the scale of whole counting procedure [14, 15]. Thresholding is a commonly used simple technique to perform background segmentation. In this study, segmentation is implemented with thresholding. Threshold value is determined with mean μ and standard deviation δ of the cell images. We set the threshold value to t = μ + x.δ according to the trials [17]. The pixel intensities under t is set to zero for R, G and B channels. The results are given in Figure 3. As clearly seen from the figure, for green channel, overlapping is less than other channels and cell boundaries are more explicit. Pre-processing step for green channel is illustrated in Figure 4. Furthermore, a background segmentation example under low and high-level noise is shown in Figure 5 and 6, respectively.
III. WATERSHED ALGORITHM FOR COUNTING

Before using watershed algorithm, histogram partitioning is applied to the cell images. The aim of histogram partitioning is to identify connected cells. At first, we obtain the histogram of pre-processed cell image. As discussed before, it is calculated for green channel. The histogram of the green channel is split into four equal interval of size 64. Because of the luminance difference between the center and edges of the cells, histogram partitioning provides useful information for counting. The partitions of green channel histogram are demonstrated in Figure 7. Then, each interval is checked from top-to-bottom and left-to-right two times and detected connected components are labelled. The components that have similar luminance take higher labels [16, 17].
In this section, we give and discuss the simulation results performed on the database obtained by communicating with the author Geisa Martins Faustino as given in reference [2]. In the database there are two groups containing 69 and 23 ESC images, respectively. For the second group the noise level is stronger than that of the first group. Gaussian radius values for Group 1 and 2 are 2 and 3, respectively. To determine the threshold value as given in Section II, is chosen as 0.3, the mean value and is the standard deviation of green channel input image.

In Figure 9 and 10, watershed applied low-noise (from Group 1) and high-noise (from Group 2) ESC images are illustrated. As it is clear from the figures, counting with naked eye will be exhausting and time consuming. Furthermore, counting results will not be reliable in these cases. Thus, the proposed automatic counting algorithm implemented for different images which are chosen randomly from Groups 1 and 2. Experimental results are given in Table 1 in comparison with the author’s before work given in [17] and with reference [2]. Because of the lack of fluorescence microscopy and experts, we are not able to measure the accuracy of the proposed method for all practical cases. However, to show the good performance of our method we compare our results with accepted studies.
Table 1. The counting results of the proposed method in comparison with reference [2] and [17].

<table>
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<tr>
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<tr>
<td>1</td>
<td>509</td>
<td>615</td>
<td>620</td>
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<tr>
<td>12</td>
<td>559</td>
<td>659</td>
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<td>16</td>
<td>404</td>
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<td>36</td>
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<td>551</td>
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<td>66</td>
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<td>72</td>
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<tr>
<td>96</td>
<td>563</td>
<td>562</td>
<td>558</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In this study, an automatic ESC counting method based on watershed algorithm is proposed. The main steps of the proposed method are explained in the corresponding sections of the study. In the first step that referred as pre-processing step, Gaussian filtering and background extraction are applied to the ESC images. Then, before performing watershed algorithm image histogram is partitioned into four parts and the best combination is determined for watershed algorithm to obtain the reliable counting results. By means of these processes, the over-segmentation problem of the watershed algorithm is also eliminated. At last, spherical contours corresponding to the stem cells are counted. Experimental results are given in comparison with the author’s before study and with one of the accepted popular paper given in reference [2]. According to the results, proposed algorithm provides consistent and promising results for automatic cell counting task. Thus, the proposed method can be used for different blood cell counting processes to provide useful result for task. Thus, the proposed method can be used for different consistent and promising results for automatic cell counting and with one of the accepted results corresponding to the stem cells are counted. Experimental processes, the over obtain the best combination is determined for watershed algorithm to algorithm image histogram is partitioned into four parts and to the ESC images step, Gaussian filtering and background extraction are applied of the study. In the first step that referred as pre- processing

REFERENCES

Developing Some Biological System of Polymer blend (PEEK-PVDF) Reinforced with Nano Hydroxyapatite and hybrid Nano (ZrO$_2$+ 3%Y$_2$O$_3$) For Internal Fixation of Bone Fracture

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I. INTRODUCTION

In the current search an attempt has been made to fabricate two groups of biological system (polymer Nano composites), consists from binary polymer blend (Polyetheretherketone (PEEK) - 7.5% polyvinylidene fluoride (PVDF)) reinforced with different Nano powders which are Nano Hydroxyapatite (HAp) and hybrid nanoparticle (ZrO$_2$+ 3%Y$_2$O$_3$) with selected weight percentage ratios of (0, 2.5, 5 and 7.5%), by melt blending with internal mixer. In the development of biomaterial, both mechanical (tensile, impact, and fracture toughness) and biological characteristics must be considered. These biological systems have characterized by using SEM, X-ray. A comparison have been done between these two groups of polymer blend Nano composites, and results clarify that by increasing the weight percentage of nanoparticle (ZrO$_2$ and, HAp) in polymer Nano composites, that the tensile strength, impact strength and flexural modulus were increased in both groups of Nano composites. Moreover it was found that the polymer hybrid Nano composites ((PEEK: 7.5%PVDF): (X%ZrO$_2$ +3%Y$_2$O$_3$)) gave higher values of mechanical characteristics as compared with their counterpart of the other group polymer Nano composites ((PEEK: 7.5%PVDF): X% hydroxyapatite). SEM results show uniform distribution of Nano powder ZrO$_2$, Y$_2$O$_3$, and fair dispersion of Nano-HA In vitro biological evaluations of the samples were done by carrying out cytotoxicity (3-[4,5-dimethylthiazol-2-yl]-2,5-phenyltetrazolium bromide) using MTT assay. Cell-material interaction with the surface of the composite was examined through inverted microscope for both developed biological system, cell viability, cell proliferation has been found to increase with increasing culture time (2,3,7) days. Moreover it was found that the polymer Nano composites((PEEK: 7.5%PVDF): (X%ZrO$_2$ +3%Y$_2$O$_3$)) revealed higher cell viability ,cell proliferation than the ((PEEK: 7.5%PVDF): (X%HA) polymer hybrid Nano composites.

Keywords- Polymer Blend, internal fixation ,biological system, Fracture Toughness, Biocompatibility.

Replacement of tooth and bone with metal implants and plates is one of the most frequently used and successful surgical procedures. The introduction of modern implants started with the work of Branemark, who in 1969 observed that a piece of titanium embedded in rabbit bone became firmly attached and difficult to remove. Current hybrid organic/inorganic composites have significant problems related mostly to their mechanical performance and their degradation in vivo [1].

However, PEEK is biologically inert which has limited its potential applications. Therefore, improving the bioactivity of PEEK is a significant challenge that must be solved to fully realize the potential benefits[2].

The concept of bioactive particulate reinforced polymer composite as bone analogue was introduced in the early 1980s by Bonfield et al.. The bone analogue material developed mimics the composition of natural bone, a natural composite material comprising mainly of collagen as the organic matrix and mineral apatite as the inorganic reinforcement. Polyetheretherketone (PEEK) Being one of the highest performance engineering thermoplastic currently available, it has received extensive applications for structural and load-bearing functions in the aerospace and marine industries. For biomedical applications, PEEK offers additional benefits including its ability to be repeatedly sterilized and shaped readily by machining and heat contouring [3].

Hydroxyapatite (HA)-reinforced polymer bioocomposites offer a robust system to engineer synthetic bone substitutes with tailored mechanical, biological, and surgical functions. The basic design rationale has been to reinforce a tough, biocompatible polymer matrix with a bioactive
HA filler. Hydroxyapatite-reinforced polymers offer the ability to tailor the composite’s elastic modulus, presumably to meet performance criteria for a particular application or implant, by varying the HA-reinforcement content[4].

Zirconia is a transition metal oxide with current applications to orthopedic implants. It has been shown to up-regulate specific genes involved in bio-integration and injury repair[5]. Rui Ma et al., incorporated 40 wt% nano-hydroxyapatite (nHA) into polyetheretherketone (PEEK) through a process of compounding, injection, and molding. The mechanical and surface properties of the nHA/PEEK composite were characterized, and the in vitro osteoblast functions in the composite were investigated [6]. Bablu Mordina et al. have prepared by melt mixing in a co-rotating twin screw extruder poly(ether ether ketone) micro/nanocomposite reinforced with N-(2-aminoethyl)-3-aminopropyl triethoxy silane treated micro- and nano-sized nickel and zirconia (0.5, 1, and 3 wt%) mechanical properties and thermal stability were characterized and the resulting nanocomposites with 3 wt% Ni and ZrO2 nanoparticles exhibit the maximum improvement in tensile and flexural strength as well as the modulus with respect to neat poly(ether ether ketone) [7]. Peng Chunzheng prepared by using the twin-screw extrusion Polyetheretherketone (PEEK) and carbon fiber (CF) composites reinforced with nano-ZrO2 particles. The results showed that the incorporation of nano-ZrO2 particles effectively enhanced the tensile properties of the composites. The tensile strength and Young’s modulus of the composites increased with content of nano-ZrO2. The incorporation of nano-ZrO2 effectively inhibited the failure of carbon fiber by reducing the stress concentration on the interface of carbon fibers. [8].

Francisco José Correa Bragaahave reported the preparation and characterization of polyvinylidenefluoride (PVDF) and hydroxyapatite (HAP) composites, analyzing the incorporation of HAP in PVDF and investigating their mechanical properties and cytotoxicity (biocompatibility) for use in bone restoration and filling[9].

The philosophy of blending two polymers is to produce a material which has properties that are tailored to a certain performance level. Since the morphology and resultant physical properties are controlled to a large extent by the miscibility and phase behavior, it is quite easy to understand why there is so much interest in controlling the phase structure in blends. The extremely high specific surface area of nanoparticles facilitates the creation of a strong interaction between the filler and matrix. Thus, nanocomposites always have unique properties resulting from the nanoscale structure [10].

To the best of our knowledge, no previous studies have reported the in vitro fibrosteoblast responses (such as cell attachment, spreading, proliferation, cell viability of L-929 cells to the PEEK+7.5%PVDF reinforced Nano Hydroxyapatite (HAP) and hybrid nanoparticle (ZrO2+3%Y2O3) composite.

So our objective is to develop two groups of biological system (polymer Nano composites), consists from binary polymer blend (Polyetheretherketone (PEEK) -7.5% polyvinylidene fluoride( PVDF )) reinforced with different Nano powders which are Nano Hydroxyapatite (HAP) and hybrid nanoparticle (ZrO2+3%Y2O3) with selected weight percentage ratios of (0, 2.5, 5 and 7.5%), by melt blending with internal mixer, and evaluate. The mechanical properties, surface morphology, chemical composition, were characterized. The in vitro fibrosteoblast functions of the composite were studied by detecting cell attachment, spreading, proliferation, and cell viability of L-929 cells.

II. Preparation of Nanocomposites

The Polyetheretherketone (PEEK) and polyvinylidenefluoride (PVDF) are desired in the granule form and were purchased from China PEEK (KLC607), the PVDF granule used in this study with particle Size (16μm). The nano particles were also supplied from china HAp (44.04nm), ZrO2(36.05-50nm) and Y2O3 (46-50nm).Polymer blend (PEEK: 7.5 wt.% PVDF) reinforced with mixture of hybrid Nano (X% ZrO2 +3%Y2O3) with selected weight percentage of Nano ZrO2 (0, 2.5, 5 and 7.5%) and Nano HAP with desired weight percentage (0, 2.5, 5 and 7.5%), were fabricated via a series of processes; as follow:- mixing, compounding, compression molding. Compounding was achieved in an internal mixer (Haake) at temperature of 365°C and mixing speed at 70 rpm. The time needed for compounding was about 5 min, depending on the amount of ZrO2, and HAp incorporated, compression molding carried out at temperature (380-400)°C using a compression molding machine.

III. Mechanical and physical tests

Tensile test samples were cut according to ASTM D 638-03 [2, 11]. Tensile test was performed with an Instron 5567 tester, carried out at ambient temperature at a cross head speed of (5mm/min); and gauge-length, 50 mm. Izod impact strength was achieved according to ASTM D256-Type 3 [12]. Using impact testing machine at the striking rate of 3.2 m/s, capacity of the pendulum: 2 joule at room temperature, a notch of 2.5 mm width with an angle of 45° was created on the sample have dimensions (3.3 mm thickness, 12.5mm width and 63.5 mm length) [12]. Three specimens for each composition were tested and the average value reported.

A. Physical Characterization

XRD pattern of the Polymer blend (PEEK: 7.5 % PVDF), blend reinforced with mixture of hybrid Nano powders (X% ZrO2 +3%Y2O3) and Nano Hap, nanocomposites were obtained using XRD, SIEMENS, D5000 (GERMANY) Theta/2Theta; XRD data were evaluated.
was achieved according to different culture time for (2,3 viability is measured as follow this test is done with microplate reader (STAT FAX 2100, USA) absorbance was measured isopropanol were incubated for further 24h, then add of sterilized MTT solution was added and the specimens serum well plate and 95% air for 24 h incubated at 37°C 250μm) rectangular specimens 929 cell suspension containing 5×10⁴ composite [(PEEK+7.5% PVDF): 7.5% HAp)]. 100 μL L polymer blend hybrid Nano composite [(PEEK+7.5% PVDF) polymer blend and polymer blend Nano composite (X%ZrO2 +3%Y2O3))]. This test is repeated four times, therefore four specimens were used for each sample test, and final results represent the average for the four specimens it was tested After finish of cell culture time, which is fixed time is (24 and 48) hours, of in vitro cell culture, morphology and cell attachment were evaluated under inverted microscope .

IV. RESULTS AND DISCUSSION

A. Structural Analysis

Figure 1 and 2 shows the XRD patterns of (PEEK, and (PEEK+7.5% PVDF) polymer blend and polymer blend hybrid Nano composite [(PEEK+7.5% PVDF): (X%ZrO2 +3%Y2O3)] as a first group and (PEEK, (PEEK+7.5% PVDF) polymer blend and polymer blend Nano composite[(PEEK+7.5% PVDF): (7.5wt X% HAp)] as second group nanocomposites respectively. Neat PEEK and (PEEK+7.5% PVDF) matrix component of the nanocomposites crystallized primarily in orthorhombic structure having diffraction peaks at about 18.7°, 20.8°, 22.9° and 28.9°, these are an agreement with other workers results [15,16]. And these corresponded to the diffraction planes of (110), (111), (200) and (211) [14,15]. No structural change was induced in (PEEK+7.5% PVDF) matrix by adding nHA, and hybrid (ZrO2%+3%Y2O3) Nano powders at different ratios contents.

Where

\[ \text{Viab. } \% = \frac{100 \times OD_{570e}^e}{OD_{570b}^e} \]
The SEM Figure 4 shown different morphologies with various contents of polymers blend composite. The fracture surface of ((PEEK: 7.5%PVDF): (X%HA) nanocomposites. shown in Figure (4 a, b and c) showed a heterogeneous morphology A co-continuous two phase structure that could be broken down into a spherical droplet structure, homogeneous micro structure, and with small regions have smoother fracture surface, which seems to indicate better interfacial adhesion between the components of composite sample.

During mixing process, the interactions between nHA and polymer blende mainly occurred through melting of PEEK and PVDF molecules, followed by wetting of molten molecules with nHAp. Figs. 4 (d), (e) and (f) show the morphologies in larger magnification (5000 ×). After mixing, polymer blend (PEEK+7.5%PVDF) molecule melt encapsulated the surface of HA nanoparticles and intimate interfacial bondings were formed in nanocomposites as observed from the dense and solid surface [16, 17].

It can be observed different sizes of spherical and oval shaped of PVDF phase were dispersed randomly in PEEK matrix it is shown through shares, moreover incompatible immiscible blends can be characterized by the domains of one phase pulling away from the domains of the other phase resulting in a droplet-in-matrix morphology (figs. d, e and f). So, PVDF particles will play as a center of energy dissipating in the PEEK matrix, and as a result, PVDF particles would respond to the triaxial stresses near the crack tip and make the localized shear yielding occurs, followed by bridging mechanism of PVDF at the crack tip zone in the PEEK matrix and plastic void growth initiated by cavitation or deboning of the PVDF particles from the surface [18].

Figs. 5(a, b, c, d, e and f), show the representative cryo-fracture surface morphology of ((PEEK: 7.5%PVDF): (X%ZrO2 +3%Y2O3)) nanocomposites which reveals that with the incorporation of hybrid nano (X%ZrO2 +3%Y2O3) there is uniform dispersion of the nano filler (ZrO2 and Y2O3) and the rough surface of the nanozirconia produces effective physical interaction and reduces the slippage of nanozirconia particulates. The SEM morphology exhibited a homogenous morphology (figure 5 (a, b and c), as co-continuous two phase structure, the SEM photos show very few of micro-cavities structure, this indicates a fairly weak interaction between the components of of hybrid nano composite especially at high ratio of ZrO2 as show in SEM photo (figure 5 (f), It was reported that the present a spherical and oval droplet particles will act as energy dissipating center in the PVDF[ 19]. Therefore from the morphological evolutions of the modified PEEK network by blending with PVDF, which were examined by scanning electron microscope and the toughening mechanism were determined to be due to spherical and oval droplet particles, followed by plastic deformation of the matrix resin as reported in [20].
It is conceivable that, with further improvement of nanoparticles clustering via particle surface modification, though more expensive, the mechanical properties can be further upgraded. Figs. 5 (b, d and f) show the morphologies in larger magnification (5000 ×) as illustrated in Figs. 5 (b, d and f) where the distribution of (X%ZrO2 +3%Y2O3) particles is quite homogeneous with some agglomeration which can be seen on the fracture surfaces at a higher magnification [21].

Fig. 5: SEM photos of the fracture surfaces of ((PEEK: 7.5%PVDF): (X%ZrO2 +3%Y2O3)) nano hybrid composites as a function of ZrO2 content (where a and d (2.5% ZrO2), b and e (5% ZrO2) and c and f (7.5% ZrO2) at different magnification (a), (b) and (c) at (1000×); (d), (e) and (f) at (5000).

B. Mechanical properties

The variations on the tensile strength, tensile modulus & elongation at break, as a function of hybrid nano (ZrO2%+3%Y2O3) and nHAp particles content have been shown in Figs. (6, 7 and 8) respectively. The tensile parameters of the nanocomposites and human cortical bone are listed in Table (1). Figs. (6, 7 and 8) suggesting that the tensile properties of nHAp/(PEEK+7.5%PVDF) and nano
Hydroxyapatite material and the compatibility of each filler. The hardness of zirconia is higher than hardness of polymeric materials, as well as has higher hardness values and higher strength properties as compared to their counterparts of the other group (nano hydroxyapatite polymer blends composites). Comparison between various loadings this hybrid as shown in Fig. 5 and 6 it was noticed that the tensile strength and tensile modulus respectively of nHAp/PEEK+7.5%PVDF) composite increases with increased nano fillers content from 0–7.5%, and this result exhibited an ultimate tensile strength of 93.502 MPa and 172.836 MPa for ((PEEK+7.5%PVDF): 7.5%nHAp) and ((PEEK+7.5%PVDF): (7.5%ZrO2%+3%Y2O3)) composites respectively, which as shown in Table 1 within the range of tensile strength of human cortical bone [17]. Most importantly the study suggests that there is no debonding occurring between the well-dispersed of nanoparticles (nHAp and nano hybrid (ZrO2%+3%Y2O3)) and polymers blend matrix (PEEK+7.5%PVDF) as shown previously by SEM, so, these results which provides a promising way to overcome the debonding issue of the PEEK-nHAp and PEEK-Nano hybrid (ZrO2%+3%Y2O3) composites [22]. The present work exhibits the increase of the tensile strength and tensile modulus of the composites with HAp nanoparticles content in a certain range, which is consistent with the results of PEEK nanocomposites with SiO2 and Al2O3 nanofillers [23, 24, 25]. According to the previous studies [26], the increase in tensile strength of the composites may be because the local stress in composites materials under load can be more easily transferred into rigid particles with the addition of nHAp and nano hybrid (ZrO2%+3%Y2O3) fillers, resulting in a higher mechanical strength, when the particles are in intimate contact with the polymer blend matrix. Moreover, these nanoparticles fillers (nHAp and nano hybrid (ZrO2%+3%Y2O3)) in composites can interrupt and delay the propagation of micro-cracks or even stop their growth via stress distribution, which is also attributed to improve tensile strength [27]. Furthermore, it was noticed that ((PEEK+7.5%PVDF): (x%ZrO2%+3%Y2O3)) composites have the higher values of tensile strength at break and young modulus as compared with their counterparts of the other group samples (nano hydroxyapatite polymer blends composites). This related to nature of both hydroxyapatite and zirconia, which have higher hardness values and higher strength properties as compared with polymeric materials, as well as the hardness of zirconia is higher than hardness of hydroxyapatite material and the compatibility of each filler with matrix especially when incorporate 3%Y2O3 nanoparticle with zirconia nanoparticle, which play an important role in the behavior and load transfer.

Generally, from Fig. (7) The tensile modulus of the polymer blend has been found to be (3.327 GPa) whereas when polymers blend matrix (PEEK+7.5%PVDF) incorporate with nano hybrid ratios of (7.5%ZrO2+3%Y2O3) the tensile modulus value reach to (7.002 GPa), this value is higher than the lower limit for the stiffness of cortical bone, i.e. 7 GPa, [28] therefore, these result in that ((PEEK+7.5%PVDF): (7.5%ZrO2+3%Y2O3)) nanocomposite is considered to be suitable for load-bearing application in orthopedics and these values fall within the lower range of the modulus of cortical bone [29].

Obviously, there is a synergistic effect of hybrid nano (ZrO2%+3%Y2O3) on the enhancement of the mechanical properties of composites. This can be seen from the graphs of tensile strength and Young’s modulus versus (ZrO2%+3%Y2O3) content for polymer blend composites with various loadings this hybrid as shown in Fig. (6,7). As is evident, the increasing trend is sharper as the ZrO2 content grows from 0 to 7.5%. The reinforcing effect of nano ZrO2 particles is more effective at a higher content of ZrO2.
Moreover, the modulus was seen to increase with nHAp content in the PEEK composite by about 19% higher than the polymer blend about 4 GPa which was closely match the lower limit of human cortical bone. This is expected, considering that the modulus of nHAp and PEEK are 85 and 3 GPa, respectively in accordance with [29]. The reinforcing effect of the nHAp particulate was evident even with the slightest inclusion of nHAp [29].

While the tensile elongation at break decreased with increasing nano hybrid (ZrO2%+3%Y2O3) and nHAp particles content in composite as shown in Fig. (8), however the decrease in tensile elongation at break of nHAp composite is lower than that of polymer blend reinforced with hybrid nano(ZrO2%+3%Y2O3) and this relate to the aforementioned reasons.

**TABLE 1: MECHANICAL PROPERTIES OF NANO COMPOSITES**

<table>
<thead>
<tr>
<th>Specimens Codes</th>
<th>Tensile Strength MPa</th>
<th>Elastic Modulus GPa</th>
<th>Impact Strength KJ/m²</th>
<th>Elongation at fracture %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEEK+7.5%PVDF(Blend)</td>
<td>85.15</td>
<td>3.32</td>
<td>7.14</td>
<td>4.390</td>
</tr>
<tr>
<td>Blend+2.5%ZrO2+3%Y2O3</td>
<td>87.2</td>
<td>4.539</td>
<td>12.48</td>
<td>4.316</td>
</tr>
<tr>
<td>Blend+5%ZrO2+3%Y2O3</td>
<td>99.83</td>
<td>5.99</td>
<td>18.07</td>
<td>4.115</td>
</tr>
<tr>
<td>Blend+7.5%ZrO2+3%Y2O3</td>
<td>172.836</td>
<td>7.207</td>
<td>19.4</td>
<td>3.8224</td>
</tr>
<tr>
<td>Blend+2.5%nHAp</td>
<td>85.101</td>
<td>3.33</td>
<td>11.26</td>
<td>4.3646</td>
</tr>
<tr>
<td>Blend+5%nHAp</td>
<td>87.357</td>
<td>3.709</td>
<td>13.22</td>
<td>4.3336</td>
</tr>
<tr>
<td>Blend+7.5%nHAp</td>
<td>93.5028</td>
<td>3.98</td>
<td>14.56</td>
<td>4.076</td>
</tr>
<tr>
<td>Cortical Bone [28]</td>
<td>50-150</td>
<td>7-30</td>
<td>1-3</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 8: Elongation at break for polymer blend (PEEK: 7.5%PVDF) as a function of nanoparticles content in polymer blends Nano-composites

Figures (9), Fig.(10) show the effect of weight ratio of hydroxyapatite and zirconia nano powders content on impact strength and fracture toughness respectively for (PEEK: 7.5%PVDF) polymer blends. It can be observed from this figure, that impact property of polymer blend has been increased with the addition of nHAp and nano hybrid (X%ZrO2 +3%Y2O3) and reaching to almost (17.54 kJ/m²) and (19.4 kJ/m²) at 7.5% nHAp and 7.5% ZrO2 respectively.

Results of the impact test of these materials is given in Table 1. Remarkable difference in the impact strength of the material can be seen with the addition of selected weight percentage of nano powders The value of impact strength has increased by more than 22% for ((PEEK: 7.5%PVDF): (X%ZrO2 +3%Y2O3)) and 20.8% for((PEEK: 7.5%PVDF): (X%HAn)). Polymer based composite materials when subjected to impact type of loading conditions, energy is absorbed in the process of plastic deformation of matrix material, debonding at matrix/reinforcement interface influence the fracture of reinforcing material. So, these composites material may be absorbs least amount of energy for its occurrence becomes prominent and that leads to fracture.

The increase in the impact strength and fracture toughness could be due to the high interfacial shear strength between nanofiller and matrix resulted from the formation of cross-links or supra molecular bonding which cover or shield the Nano fillers which in turn prevent propagation of cracks. Also the crack propagation may be changed by good bonding between nanofiller and resin matrix [30]. The small size and high surface area and relatively low concentration may helped in a good distribution of these fillers that may cause a restricted motion of macromolecule chains and enhance mechanical properties [31]. Moreover if the compatibility of the filler particles with the matrix material is not good, the crack blunting at the filler particle location will play an important role and again leads to the same conclusion that the nanofiller prevent the propagation of cracks which lead to increase fracture toughness as shown in Fig.10 [29]. In case of reinforced nano particles nHAp, compatibility with the matrix resin seems to be fair through scanning electron microscopic observation (Figure 4) While the compatibility of the hybrid (X%ZrO2 +3%Y2O3) with polymer blend ((PEEK: 7.5%PVDF) is better than counterpart group as shown in (Fig. 5) which may be resulted from the addition of small amount of nano yeteria which lead to enhanced compatibility of nano zirconia with polymer blend. For that reason the impact strength and fracture toughness of ((PEEK: 7.5%PVDF): (X%ZrO2 +3%Y2O3)) is higher than the counterparts of the other group ((PEEK: 7.5%PVDF): (X%HAn)). Beside that the increase in impact strength may be due to low loading of filler which is less than 10% as compared with microfiller[32].
the difference compared to 
(7.5%ZrO2 +3%Y2O3)) show higher absorbance as
compared to polymer blend and control due to the
formation of apatite on((PEEK: 7.5%PVDF): 7.5%
hydroxyapatite) and the ability of nHAp to increase the
growth of apatite as reported in [35].

Figure 11 and 12 show the MTT-assay results for the
polymer blend (PEEK: 7.5%PVDF) ((PEEK: 7.5%PVDF):
7.5% hydroxyapatite) and ((PEEK: 7.5%PVDF):
(7.5%ZrO2 +3%Y2O3)) nanocomposites up to 7 days
incubation compared with control. In the process, the
Yellow water-soluble MTT (3-(4,5-dimethylthiazol-2-yl)-
2,5 diphenyltetrazoliumbromid) is metabolically reduced in
viable cells to a blue-violet insoluble formazan. The
number of viable cells correlates to the colour intensity
determined by photometric measurements after dissolving
the formazan in alcohol. Fig.10 revealed that there is a
gradual increase in the light absorbance with culture time
for the polymer blend (PEEK: 7.5%PVDF), (PEEK: 7.5%
hydroxyapatite) and (PEEK: 7.5%PVDF): (7.5%ZrO2 +3%Y2O3)) nanocomposites seeded with the mouse fibroblasts. Compared with polymer blend and control, all of the nanocomposites show higher absorbance values. This indicates that the nanocomposites provide favorable surface sites for cell proliferation. More importantly, the nanocomposites with (7.5%ZrO2 +3%Y2O3)) show higher absorbance as compared to the nanocomposites with nHAp contents after 3day and after 7 days but, at the same time the difference between the two groups are not very significance. Thus, the((PEEK: 7.5%PVDF): (7.5%ZrO2 +3%Y2O3)) nanocomposites has higher cell activity or biocompatibility which revealed that the nanohybrid(7.5%ZrO2+3%Y2O3) have no cytotoxic effect as reported in[33,34], and competing with the ((PEEK: 7.5%PVDF): 7.5%
hydroxyapatite) which has good biocompatibility as
compared to polymer blend and control due to the
formation of apatite on((PEEK: 7.5%PVDF): 7.5%
hydroxyapatite) and the ability of nHAp to increase the
growth of apatite as reported in [35].

To obtain further information on cellular adhesion, optical
microscopy was used to observe the distribution of L-929
cells next to the extraction of Nano composite samples after various times of incubation period, points days incubations a. control sample, b. polymer blend ((PEEK+7.5wt%PVDF) sample, c. Nano composite(Blend+7.5%nHAp) and d. Nano hybrid composite( Blend+7.5%ZrO2 +3%Y2O3) sample.
ZrO$_2$+3%Y$_2$O$_3$), nHAp powder does not show any sign of cytotoxicity. Fig. 13(a,b,c,d) shows images of L-929 fibroblast cells on nanocomposites which show that after 24 hours the spread of cells was found in control as well as in polymer blend (PEEK: 7.5%PVDF), ((PEEK: 7.5%PVDF): 7.5% hydroxyapatite) and ((PEEK: 7.5%PVDF): (X%ZrO$_2$+3%Y$_2$O$_3$)) nanocomposites. After 48 hour the cell spread was found to be higher as compared to 24 hour which indicates that nanopowders hybrid(7.5% ZrO$_2$+3%Y$_2$O$_3$) and nHAp did not cause any toxic effect on cells. Moreover, cells attached well to these materials, proliferated, and formed a dense cell layer with numerous cell–cell contacts (Fig. 3.12,a,b,c,d). No significant differences were observed among cells with nano hybrid(7.5% ZrO$_2$+3%Y$_2$O$_3$) [Fig. 13(a,d)], and control cells in terms of the morphological characteristics of the fibroblasts which agreed with [36]. Fig.13 shows a regular pattern of cell growth of fibroblast cells which is characteristic of a test conducted on nanopowders hybrid(7.5% ZrO$_2$+3%Y$_2$O$_3$) and nHAp. The in vitro study conducted on cytotoxicity of ((PEEK: 7.5%PVDF): (X%ZrO$_2$+3%Y$_2$O$_3$)) nanocomposites, shows higher biocompatibility as compared to counterpart group of and ((PEEK: 7.5%PVDF): 7.5% hydroxyapatite) nanocomposite produced. Also, as appeared in Fig.12 (a,b,c,d) the numbers of living cells on ((PEEK: 7.5%PVDF): (X%ZrO$_2$+3%Y$_2$O$_3$)) were found to be increased and larger in size which as compared to polymer blend (PEEK: 7.5%PVDF), and((PEEK: 7.5%PVDF): 7.5% hydroxyapatite) as well as controls (Fig.13(a,b,c,d) after seeding cells for 24 hour and 48 hour.

(b)The cell morphologies of polymer blend (PEEK+7.5%PVDF) cell growth B1 after 24 hour and B2 after 48 hour

(c)The cell morphologies of ((PEEK: 7.5%PVDF): 7.5% hydroxyapatite) cell growth C1 after 24 hour and C2 after 48 hour

(d)The cell morphologies of ((PEEK: 7.5%PVDF): (X%ZrO$_2$+3%Y$_2$O$_3$)) cell growth D1 after 24 hour and D2 after 48 hour

(a)The cell morphologies of control cell growth A1 after 24 hour and A2 after 48 hour

(b)The cell morphologies of polymer blend (PEEK+7.5%PVDF) cell growth B1 after 24 hour and B2 after 48 hour

(c)The cell morphologies of ((PEEK: 7.5%PVDF): 7.5% hydroxyapatite) cell growth C1 after 24 hour and C2 after 48 hour

(d)The cell morphologies of ((PEEK: 7.5%PVDF): (X%ZrO$_2$+3%Y$_2$O$_3$)) cell growth D1 after 24 hour and D2 after 48 hour
V. Conclusion

Experimental investigation was conducted to evaluate and compare the effect of addition of different nanoparticles on characterization of prepared nanocomposites using in internal fixation of bone fracture. The following conclusions were drawn based on the present work:

1. The tensile strength of hybrid nanocomposites ((PEEK: 7.5%PVDF): (X%ZrO₂ +3%Y₂O₃)) value was increased from 85.1527 to 172.836 MPa while tensile strength of ((PEEK: 7.5%PVDF): (X%HA)) increased from 85.1527 to 93.5028 MPa when addition nanoparticle powder to prepared polymer blend.

2. The increase in tensile strength and elastic modulus in ((PEEK: 7.5%PVDF): (X%ZrO₂ +3%Y₂O₃)) was higher than in the counterpart group((PEEK: 7.5%PVDF): (X%HA)), however both prepared nanocomposite have tensile properties that closely match the tensile strength of cortical bone.

3. Impact strength of ((PEEK: 7.5%PVDF): (X%ZrO₂ +3%Y₂O₃)) increase by about 23% which was higher than in ((PEEK: 7.5%PVDF): (X%HA)), however the impact strength of this group increased by about 21%.

4. The results of mechanical test show a promising developed biomaterial that can be used in internal fixation of bone fracture, represented by ((PEEK: 7.5%PVDF): (X%ZrO₂ +3%Y₂O₃)), ((PEEK: 7.5%PVDF): (X%HA)) using low loading nano filler less than 10%.

5. SEM micrographs of cryo-fracture surface morphology of both prepared nanocomposite showed homogeneous micro structure, and with small regions have smoother fracture surface, which seems to indicate better interfacial adhesion between the components of composite sample. As well as uniform dispersion of the filler and the rough surface of the nano zirconia produces effective physical interaction and reduces the slippage of nano zirconia particulates.

6. The XRD patterns of polymer blend, polymer blend, hybrid Nano composite [(PEEK+7.5% PVDF): (X%ZrO₂ +3%Y₂O₃)] and Nano composite[(PEEK+7.5% PVDF): 7.5wt.% HAp)] nanocomposites indicated No structural change was induced in PEEK by adding nHA, and hybrid(ZrO₂+3%Y₂O₃) of different contents.

7. The developed nano composites exhibited excellent biocompatibility, bioactivity and on the basis of MTT assay. The cell viability was found to get promoted with increasing incubation time for toughened polymer blend with different nanopowdered and the neat blend, however it can be noticed that the Nano composite[(PEEK+7.5% PVDF): (7.5%ZrO₂+3%Y₂O₃)] show higher cell proliferation, cell attachment, and non-cytotoxic effect of the hybrid(7.5%ZrO₂+3%Y₂O₃). Moreover[(PEEK+7.5% PVDF): 7.5wt.% HAp)] also provide higher surface activity as compared to polymer blend as well as control. which means the nano hybrid (7.5%ZrO₂+3%Y₂O₃) and nHAp, exhibited active biological responses to physiological environment and promotes fibroblasts activities more effectively when compared to other nano materials.

8. From optical micrographs showing the cell morphologies in different states of cell growth on PS sample including division and flattening after 24 hour we can noticed that cell is well attached to the surface of nanocomposites. Moreover the polymer blend (PEEK: 7.5%PVDF incorporated with nano hybrid(7.5%ZrO₂+3%Y₂O₃) show best cell attachment next to control as compared the counterpart polymer hybrid Nano composites ((PEEK: 7.5%PVDF): 7.5% HAp) which make this new developed biopolymer blend a promising material for load bearing biomaterial.

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Active Contour Based Developmental Hip Dysplasia Diagnosis with Graf Method

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Abstract— In this article, a study was carried on ultrasound (US) images for the automatic diagnosis of the disease of the developmental hip dysplasia (DDH). It was aimed with this study at minimizing the errors of the experts in DDH diagnosis. As a first step in the study; commonly known as the images and reduce noise in the US image, image filter are applied to improve the quality. In the second stage; by using Active Contour Model method it was determined acetabular roof and labrum areas. In the third stage; alpha and beta angles that is necessary to be applied Graf method and used DDH diagnosis are determined by using various morphological image algorithms on the image. In the last stage, the classification of Graf method was made and the performance of the system was measured by comparing expert data and the results. According to type conditions of Graf method, in the images of 40 out of 50 it was found the same due to software which was designed with expert data. In the remaining 10 images, expert result and program result are rather close especially for alpha angle. As a result, the success rate of the system for the 50 image is 80%. When considered the parameters such as the difficulty of physical examination of DDH diagnosis, decreasing quality of life in the people suffered from this disease, limb shortening, limping, functional disability, treatment costs, based on expert data and relativism of applying of Graf method on US images, the importance of DDH diagnosis system supported computer is seen.

Keywords— Developmental Hip Dysplasia, Ultrasound, Active Contour Model, Image Processing

I. INTRODUCTION

Developmental dysplasia of the hip (DDH) is structural dysfunctionality resulted from or dislocation of the hip, femur (thigh) head and acetabulum (cup). The incidence of this disease prevalence (of which the risk of) in the world identified as 1/3000 higher than in Japan and the Mediterranean Basin [1]. DDH can be treated successfully with early diagnosis. Delays in diagnosis and treatment of extremity (limb) brevity can cause restricted movement disorders such as claudication and functional disability. Diagnosed in the newborn period and successful in 96% of infants who were treated as anatomical and radiological can be obtained in normal development [2]. There is no chance of conservative treatment in the children that are in toddler age. To get successful results in all cases with surgical treatments is also impossible. Even if surgical treatment is successful, negativities is too large to be ignored [3].

To determine DDH incidence, differences in the definition of this abnormal situation in the hips, method differences in examining of hip, knowledge level of the person carrying out the examination vary depending on the characteristics of the studied communities. The incidence of approximately 1 in 1000 births, birth is stated to range between 100 3-4 [4]. Physical examination and ultrasonography (US) seen with higher frequency are determined by imaging [4].

Scanning hip US widely used in the world. The reason is that cheap sonography extremely common and safe. It is estimated that by introducing the world every four base units [5]. Furthermore, US usage is to diagnose the possibility of eliminating the risk of radiation intake in newborn infants.

US findings and hip development disorder can be defined, and treatment can be planned. Technically, Graf, Mortar, Harcke, and Terjesen methods are used [5]. Graf method is easy to learn compared to other methods is a simple method and is the most popular method worldwide hip US [6]. Europe has long been used in the study of newborn hip [7].

Fig. 1. US image for the diagnosis of DDH: a) raw image, b) manually determined α and β angles, c) diagnosis of DDH

Graf method is typing of hip morphology of hip angles that was measured on sonogram, and this was carried on tilted baby, and this is imagined on trochanter major in the standard plan of specific anatomical points with parallel placed the transducer to the body axis. Then the image shown in the standard plan
and as seen in Figure 1, the hip joint angles ($\alpha$ and $\beta$) is determined by the value morphology [8]. However, overall poor image quality makes it difficult to determine the angle of the hip joint radiologist.

Roof angle alpha bone, cartilage roof gives information about the beta angle. There is a relationship between decrease in the value of the acetabular angle alpha and dysplasia, and in clinical studies, alpha angle lower thighs is seen as the hip that can be dislocated [9].

The Graf method is examined four groups in hip ultrasound identification. Alpha angle values are used in the original grouping. Beta angle values are secondary typing (type 1a-1b and type 2c-D in differentiation), the baby several months by type 2a-2b distinction, such as whether the labral degeneration 3a-3b distinction and perichondrium morphology types used in 3-4 divisions (Figure 2) [10].

There are very few studies in the literature related to computer-aided diagnosis of DDH. The first study in the literature that was tried to recognize automatically is seen in 1998. Overhoff et al. [11] undertook a study on femoral automatically detect over 10 different images. not found any information about the performance of the system. Luis-Garcia and Lopez-Alberola have done several studies on the diagnosis of DDH. In their study, they tried to determine femur and acetabulum areas by segmenting US images. In their first study based on dividing of muscle area that are nonlinear and in this study, Dynamic Shape Priors method was used. Dynamic way of priority was also used in these studies, they suggested automatic creating in segmentation flow as well as anatomical knowledge. In their studies, they reported that the first impressions on real images showed promising results [12]. In 2006, they presented segmentation method for hip joint from 3D ultrasound data. Kullback-Leibler distance measurement is used as the actual difference measure; energy minimization is performed by estimating the optimal parameters of sphere and parabolic so that the femoral head and the acetabulum easier segmentation. Experimental results for a number of data set in this study; this approach has shown that the success of using simple geometric approach to the anatomy of the hip joint [13].

In 2007, ultrasound images of based on the Rayleigh distribution parameter which'n local estimate of for analyzing the ultrasound signal to have a new technique adopted as a model, the local estimator, the original ultrasound image conversion, it has been observed that the hip ultrasound images of increasing the feasibility allocated between different regions on [14]. Han-Yang et al., tried to implement a computer-aided design system for the treatment of DDH. Firstly, they used classic segmentation method in their studies, but they reported that these methods were giving unreliable results because of the difficulty of processing the images of US. Then they used a mixture of images-based algorithm for partial-volume segmentation and stated that they have achieved remarkable results [15].

In the dividing of US images used in diagnosis of DDH disease is seen not fully achieved results. By this study, this operation to be made independent from the DDH experts fault diagnosis it is provided with a high success rate.

II. MATERIAL

In the study, it was benefited from the US images used to diagnose DDH. Images are taken from Selcuk University Faculty of Medicine, Radiology Department. The US device used to collect the images is Toshiba Apio 400. Image set, each image section has been created under the supervision of specialist doctors radiologists examined individually. It was provided to be labeled correctly by using radiology report depending on the images taken in the standard form of sonogram. Besides the raw images obtained, there are also images that have been diagnosed by the experts according to Graf method.

The raw hip US images is gray level and the JPEG format. Images are irrelevant background areas in 800x600 pixels. US raw images obtained for use in this study and a sample image is diagnosed by the expert according to the state of the Graf method is given in Figure 3. A total of 25 patients, including 50 from the right and left hip image were obtained. Patients’ ages ranged from 0-3 months.

![Fig. 2 Types of hip according to Graf classification](image)

![Fig. 3 The ultrasound images used in the study a) raw image b) diagnosed image](image)
III. METHOD

In this study, a software was performed by using image processing techniques to provide the computer-aided diagnosis of DDH disease. Figure 4 shows a block diagram of the study.

Overall poor image quality makes it difficult to determine the angle of the hip joint for radiologist. Therefore, as the first; commonly known as the images and reduce noise in the US image, image filters have been applied to improve the quality (Mean, Median, Gaussian, Wiener, Perona & Malik Lee, and Frost). The most effective one (wiener) was applied to all images by measuring the effect on the image [16].

B. Active Contour Model

In recent years, ACM has been commonly used for medical image segmentation. ACM is known as basic idea of the overall development curve fitting method curves converge to object called [18-22]. It is selected a curve segments around the object and then according to effects of internal and external forces converge process is performed. When representation of the curve, ACM is divided two as open [20, 23] and close [19, 24, 25]. Snake model that made open demonstration of growing curve can be shown as an example for open ACM [20, 23]. Level sets modal that change the curve as parametric with a certain distance function can be shown as an example for close ACM [21, 26, 27]. Generally, close ACM’s can cope with topological deformation more than open ACM’s.

Unlimited ACM presented by Chan and Vese is a successful segmentation study that were used in many studies on various subjects [19]. It is based on Curve distribution, Mumford-Shah method and level set techniques [27]. It is known as Chan-Vese (CV model) region-based segmentation algorithm. This method is less sensitive to noise than other contour method. This model includes a function similar to the values of our energy to other mini-contour model. While determining the interior lines, it moves without depending on initial value. This feature is separated from the snake model. Zero level set of the surface image is a moving curve and this curve detected the object. The changes such as splitting and merging can be detected automatically. According to this method, an image is divided into homogeneous regions using this level function. This region is composed of image parts containing closed area value [28].

C-V algorithm divided by C is off limits u_0 official F(c_1, c_2, C) describes the energy function. This function is shown in Equation 1.

\[ F(c_1, c_2, C) = \mu.\text{Length}(C) + v.\text{Region}(\text{inner}(C)) + \lambda_1 \int_{\text{inner}(C)} |u_0(x, y) - c_1|^2 \text{d}x\text{d}y + \lambda_2 \int_{\text{outer}(C)} |u_0(x, y) - c_2|^2 \text{d}x\text{d}y \]  

(1)

In equation 1, \( \mu \geq 0, \lambda_1, \lambda_2 > 0 \) are fixed parameters, \( c_1 \) and \( c_2 \) are changing parameters, also they are average value respectively remaining areas outside and inside of C contour. The first term is regularization term that prevents contour merging with a small area. The last two terms are fitting terms [29].

IV. IMPLEMENTATION

A software that uses computer-aided Graf methods to put the diagnosis of DDH study was carried out on Matlab 8.3. Received by experts from US device 50 DDH image taken is processed by software designed and Graf method may be practiced alpha and beta angles were determined. Classifications in Graf method are carried out with these determined (alpha and beta) values. In the final stage, the outputs of software and the classifications which were applied by the radiologist were compared.
In the first stage of our study, in the phase of our work, in order to facilitate the processing of US images; when the applied filter on the effect of quality improvement as measured DDH images; observer sensitivity, resulting image quality measurements and images made with segmentation of tests, wiener filter the ilium, acetabular segmentation of the roof and the labrum is determined to be more successful than other filter [16]. Consequently, all obtained images were passed through wiener filter in pre-process stage.

In the second stage, wiener filter applied by applying the method improves the quality of images ACM estimated ilium region have been identified on the image. C-V ACM is used for segmentation of the ilium. As a result of estimated segmentation, the most-right and left areas were determined (Figure 5).

In the third step of our study, alpha and beta angles required to be applied Graf method provided to be determined used for DDH diagnosis. There must be a reference point drawn on ilium area and from base line to determine alpha and beta angles. The feature of this reference point in the negotiations with radiology specialists; the ilium area is divided. For the clarification of the estimated ilium identified in the previous section ACM method was once repeated between R-E, L-E and C.

Various morphological operations are applied to the resulting image in certain provinces. Thinning of the algorithm was first segment (thinning) has been converted into a pixel line subjected to the process (frame extraction). In this way, our image has taken a structure consisting of branches. After the thinning process is performed, the branch, and pruning was found that formation of unwanted images for the screening of the faulty branch (pruning) subjected to the process. Finding knot point to determine the latest stage in the branchpoint process is performed (Figure 6).

Fig. 6 Morphological processing for detecting the reference point: a) Ilium identified in the region of estimated ilium, b) Segmentation results, c) thinning results, d) as a result of pruning, e) branch points process results.

After determining the correct reference point, there are two areas that need to be find. These are the acetabular roof and labrum. The line that was drawn between acetabular roof and reference point is "Roof Line" and is used to determine alpha angles. The line between labrum and reference point is "Inclination Line" and is used to determine beta angles. In the determination of these two areas, it was taken estimated areas and segmentation process was performed. It was benefited C-V ACM algorithm for this segmentation process (Figure 7).

Fig. 7 Labrum and acetabular roof segmentation: a) segmentation results, b) determining the intersection point.

In the final stage of the study, reference, labrum and acetabular roof points were determined (Base Line, Roof Line, Inclination Line), and it was drawn lines between in these points, and beta and alpha angles were measured (Figure 8). The classification of Graf method was made in terms of these angles values.
In the study, a computer-aided system was designed in order to make diagnosis of DDH. Through a pre-process stage, the acetabular roof and labrum areas were determined, alpha and beta angles were also determined, and the diagnosis was made utilizing the Graf method. In evaluation stage, Graf alpha and beta angles, from the designed software alpha and beta angles diagnosis were compared (Table 1). In Table 1, the computer results which don’t match with expert evaluation is indicated as red. On the other hand, the missing result according to the beta angle is marked as green in Table 1.

V. RESULTS

Upon analyzing Table 1; when we look at only Type I, in 40 out 50 images were matched with expert evaluation, on the other hand, in 38 out 50 images were matched with expert evaluation by looking Type I and Type II together. As a result, the success rate is 80% based on only Type I, 76% based on Type I and Type II together.

VI. DISCUSSION

In the expert assessment of the results that calculated in the study; It was stated that the alpha value was near 60 degree had been an obstacle for the performance of the system. Because Type I Type 2 separation depends on keeping the value of alpha is 60 degrees or higher. For this reason experts; specifically stated that the results of the exit near the equivalent of close to 60 degrees of angle alpha. The shifting for 1-2 degrees completely change the diagnosis. These changes directly affect the performance of the system. For these reasons, with the recommendation of a system to alternative Graf method system success may increase. This system may be determined by Artificial Intelligence Applications used very often today.

TABLE I

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Fig. 8 Alpha and Beta angles with reference point.
ACKNOWLEDGMENT

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Structural, Elemental and Molecular Characterization of Human Articular Cartilage

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Abstract—The articular cartilage overlying the bone consists of a network of collagen fibres. This network is essential to cartilage integrity, usually suffering damage in degenerative joint diseases such as osteoarthritis. We have been applying a number of techniques to study the bone–cartilage interface and of changes occurring in this with disease. The bone-cartilage samples with disease were investigated for their structural, elemental and molecular properties. The bone-cartilage samples with disease were characterized by scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDX) and Fourier Transform infrared spectroscopy (FTIR) and Fourier transform (FT) Raman spectroscopy. The energy dispersive X-ray (EDX) analysis confirmed nearly stoichiometric samples. The Raman spectra made it possible to monitor the changes in the main bone constituents: the mineral component with the apatite band at 960 cm⁻¹, the organic component with the collagen amide III band at 1268 cm⁻¹. Present results have been obtained on sections of bone not displaying evidence of an osteoarthritic lesion and can be used as a baseline against which diseased bone can be compared.

Keywords—Bone-cartilage, Raman, SEM-EDX, FTIR.

I. INTRODUCTION

Bone is a complex tissue which integrates two basic components, organic (matrix) and inorganic (mineral) material [1]. Its high strength and fracture toughness is achieved by a unique architecture of organic and inorganic phases [2–4]. It contains nano sized mineral platelets (essentially carbonated hydroxyapatite) [5], protein (mainly collagen type I), and water [3, 6]. The matrix makes up 30–40% of the total bone material and consists of collagen and other non-collagenous protein sand lipids [6]. Around 85–90% of the total protein content is made up by collagen fibrils. The mineral substance is mainly a carbonated form of crystalline calcium phosphate with a total percentage in bone material of 60–70% [7]. Therefore, because of the structural complexity of bone, its healing is an extremely complex process which has been under extensive investigation for many years [8]. Articular cartilage has an extracellular matrix composed primarily of water, type II collagen fibrils and proteoglycans [9]. Histologically, articular cartilage has unique variations in its morphological structure and molecular composition across its tissue depth, which is commonly considered to comprise three sub-tissue zones based on local fibril orientation [10]. These three zones are (a) the superficial zone (SZ) where the collagen is oriented parallel to the articular surface, (b) the transitional zone (TZ) where the collagen is oriented rather randomly, and (c) the radial zone (RZ) where the collagen is oriented mainly perpendicular to the articular surface. The critical role of the collagen matrix in cartilage is to preserve the tissue integrity where any alteration of the collagen microstructure due to tissue lesions will inevitably disrupt the molecular environment, consequently modifying the mechanical properties of the tissue.

Several microscopic imaging techniques have been used to study the load-induced deformation of the collagen matrix in articular cartilage. For example, microscopic MRI (mMRI) has been successfully used to image the modification of the tissue morphology in intact tissue blocks based on the proton...
signals in water molecules [11]. Scanning electron microscopy can directly visualize the effect of mechanical loading on the organization of the collagen fibrils in cartilage matrix [12]. The technique of Fourier transform infrared (FT-IR) spectroscopy is a powerful tool to study the previously described changes in degenerative cartilage at the molecular level. Raman analysis is sensitive to molecular orientation, and discerning between orientation and compositional contribution is crucial as bone is comprised of mineralized collagen fibres with alternating orientation within successive lamellae. The capability of Raman microspectroscopic analysis to distinguish between structural and chemical changes in bone were reported [13], by exploiting the dual influence of composition and structure with in the sample on the Raman signal [14].

Two human femoral head cartilage specimens from the autopsy of humans are reported in this paper. While one of the samples is of a osteoarthritic cartilage the other is a healthy cartilage. The healthy cartilage was due to a femoral head fracture. Prior to the sample analysis, there were no fixations, embedding or surface processing. This work is an effort to characterize the healthy and diseased bone-cartilage by using a combination of techniques such as scanning electron microscopy- energy dispersive X-ray spectroscopy (SEM-EDX), FT-IR and Raman spectroscopy. The aim of this study is to make comparison of structural, elemental and molecular properties of healthy and diseased bone-cartilage samples.

II. MATERIALS AND METHODS

Human femoral heads from total hip replacement procedures were used, due to surgical intervention in response to a degenerative joint disease. The femoral heads were sourced from the department of Orthopedics and Traumatology at Kocaeli University (Turkey). Using a water-cooled diamond saw (Isomet 1000 Precision) several sections at certain thicknesses were cut perpendicular to the articular surface from the superior aspect of the femoral head, the sections being of different diameters (15–20 mm), with thicknesses ranging from 200 μm to 300 μm. These sections were subsequently soaked in distilled water to remove any bone marrow and loose particulate matter. Morphological and elemental investigations were conducted on a scanning electron microscopy (Zeiss Supra 50 VP model SEM-EDX) with an acceleration voltage of 25 kV. Absorbance FT-IR spectra were obtained using a Thermo Scientific spectrometer in the range of 4000–400 cm⁻¹ using KBr pellets at room temperature. The resolution was 2 cm⁻¹, and the number of scans was 30.

An inViaReflex™ and an inViaQontor Raman microscope (Renishaw plc, Wotton-under-Edge, UK) were used. The spectrometers were configured with a diode laser excitation (785 nm) with the laser power of 300 mW, a 600 g mm⁻¹ grating (Reflex) / a 1200 g mm⁻¹ grating (Qontor), a motorized XY stage and a charge coupled device (CCD) detector. A line-shaped laser output was focused onto the sample through a microscope using a ×20 microscope objective.

III. RESULT AND DISCUSSION

The surface morphology and elemental analysis of the healthy and diseased femoral heads were characterised by scanning electron microscopy and energy dispersive X-Ray spectrometer. Fig. 1 shows the SEM images of the osteoarthritic femoral head cartilage sample and healthy cartilage (femoral head fracture) sample.

Fig. 1. SEM images of healthy and diseased cartilage samples.

Fig. 1 shows that femoral head fracture cartilage have a smooth surface structure. The cartilage surface contains the
presence of lacuna, chondrocytes and the chondroblasts structures. For the osteoarthritic femoral head cartilage, the level of surface deformation increased. Because of deterioration cartilage surface has occurred as the disease progresses. Consequently, the surface properties significantly, changed due to with cause deformation and diseases.

Fig. 2 shows the EDX data of the osteoarthritic femoral head cartilage sample and healthy cartilage (femoral head fracture) sample.

Fig. 2. EDX data a) healthy and b) diseased cartilage samples.

Fig. 2 shows that healthy and diseased cartilage samples have elements such as Ca, P, S, C, etc. It is evident that healthy bone cartilage sample has more amount of elements such as calcium, phosphate, etc., than the diseased cartilage.

Fig. 3 shows the RAMAN spectra of the osteoarthritic femoral head cartilage sample and healthy cartilage (femoral head fracture). Surface StreamLine images were obtained in an area of 773.9µm x 248.5 µm, using 90 mW laser power, 4 seconds/line acquisition time, and a 7.1 µm step size.

The human osteoarthritic cartilage tissue section is shown in Fig. 4. The data collection points are indicated by stars and numbered as: 1-) the cartilage, 2-) bone-cartilage interface, 3-) bone section, close to the interface and 4-) bone middle section.

Fig. 4. White light image of a healthy cartilage section. The stars indicate where point spectra were acquired.

Fig. 5 shows the Raman spectra from the four different regions that are indicated in Figure 4. The prominent bands are labeled. The $\nu_1$ phosphate stretching vibration at 960 cm$^{-1}$ is the strongest marker for bone mineral. The broader bands are assigned to amide III ($\sim 1239$ and 1268 cm$^{-1}$), the C–H bending mode ($\sim 1450$ cm$^{-1}$), and amide I ($\sim 1668$ cm$^{-1}$). The amide I at $\sim 1668$ cm$^{-1}$, and amide III $\sim 1239$ and 1268 cm$^{-1}$ peaks are mainly due to the presence of collagen, while the C–H bending band at $\sim 1450$ cm$^{-1}$ is present in both collaginous and noncollagenous organic moietyes. When the spectra are compared Number 1 through Number 4, from the
interface to the bone middle section, the relative intensity of the phosphate stretching vibration is increased as a result of increase in the mineral content. Whereas, the relative intensity of the band vibrations that are responsible from organic content of the tissue section is decreased.

Fig. 5. Raman spectra acquired from the locations marked by the stars in Figure 4.

The osteoarthritic femoral head cartilage sample was analyzed by Live Track StreamLine and the image of the sample illustrated in Figures 6 and 7.

Fig. 6. White light image of the osteoarthritic femoral head cartilage sample, as seen in Fig 3. The white box indicates the Surface Stream Line analysed area. At the cross hair position a single spectrum is acquired.

Fig. 7. An example spectrum from the cross hair position shown in Fig 6.

The spectrum displays mainly signals that are coming from the protein content, such as tryptophan, C-C protein, proline, hydroxyproline (874 cm\(^{-1}\)), phenylalanine (1003 cm\(^{-1}\) and 1030 cm\(^{-1}\)), amide III (collagen type I, 1239 cm\(^{-1}\) and 1268 cm\(^{-1}\)), CH from protein (1450 cm\(^{-1}\)) and amide I (collagen type I, 1668 cm\(^{-1}\)). Besides protein signals, the glycosaminoglycan and hydroxyapatite (PO\(_4^{3-}\)) vibrations are also evident in the spectrum. The hydroxyapatite signal scores are relatively low values compared with the bone tissue sections.

Fig. 8-9 shows FT-IR absorbance spectra of the samples. Two samples were characterized by use of FTIR spectrometry (Thermo Scientific, Erzincan, Turkey) as described. Data were collected in the absorption mode between 4000 and 400 cm\(^{-1}\), with resolution 4 cm\(^{-1}\). We used previous assignments of absorption bands. For healthy cartilage regarding carbonated apatite [\(\text{CA} : \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_x(\text{CO}_3)_y\)], the \(\nu_1\) and \(\nu_3\) P-O stretching vibration modes were measured at 723 cm\(^{-1}\) and 1163 cm\(^{-1}\) respectively, and the O-P-O \(\nu_4\) bending mode corresponded to the doublet at 531 cm\(^{-1}\). Regarding m-CPPD, O-P-O bending was recorded at 514 and 500 cm\(^{-1}\). Amid I, Amid II and Amid III infrared bands were measured at 1740 cm\(^{-1}\), 1464-1377 cm\(^{-1}\) and 1201 cm\(^{-1}\) respectively. These values change for diseased cartilage. For healthy cartilage regarding carbonated apatite [\(\text{CA} : \text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_x(\text{CO}_3)_y\)], \(\nu_3\) P-O stretching vibration mode was measured at 1026 cm\(^{-1}\), and the O-P-O \(\nu_4\) bending mode corresponded to the doublet at 517 cm\(^{-1}\). Amid I, Amid II and Amid III infrared bands
were measured at 1747-1646 cm\(^{-1}\), 1540-1457 cm\(^{-1}\) and 1338-1200 cm\(^{-1}\) respectively.

Fig. 8. FT-IR spectra of healthy cartilage samples.

Fig. 9. FT-IR spectra of diseased cartilage samples.

IV. CONCLUSIONS

We used SEM-EDX, FT-IR and RAMAN spectroscopy to characterize the healthy and diseased bone-cartilage samples. SEM results show that the surface properties changed significantly due to deformation and diseases. It was found quantity of basic elements of the diseased bone-cartilage sample decreased. RAMAN spectrum displays mainly signals that are coming from the protein content, such as tryptophan, C-C protein, proline, hydroxyproline. The results obtained FT-IR analysis through also suggests disruption of bone cartilage structure. The results reveal that there are structural, elemental and molecular differences in healthy and diseased cartilages.

REFERENCES

Stiffness Analysis of Above Knee Prosthesis

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Abstract—While a healthy human walks, his or her legs mutually perform good repeatability with high accuracy. This provides an esthetical movement and balance. People with above knee prosthesis want to perform walking as esthetical as a healthy human. Therefore, to achieve a healthy walking, the above knee prosthesis must provide a good stiffness performance. Especially stiffness values are required when adding a second axis movement to the ankle for eversion and inversion. In this paper, stiffness analysis of above-knee prosthesis is presented. The translational displacement of above knee prosthesis are obtained when the prosthesis is subjected to the external forces. Knowing stiffness values of the above knee prosthesis, designers can compute prostheses parameters such as ergonomic structure, height, and weight and energy consumption.

Keywords—Stiffness analysis, above knee prosthesis, joint stiffness, prosthesis, accuracy

I. INTRODUCTION

It is required that serial robots have to make their tasks with a high accuracy, high precision and high stiffness [1]. The stiffness of robot manipulators generally provides to obtain the desired position and force commands with high accuracy [2, 3]. If the stiffness at the end point of robot manipulator is modified and identified accurately, it would be possible to compensate coupling and posing errors caused by the external forces [4].

Dumas et al. [1] introduced a method for the identification of the joint stiffness values of an industrial 6-DOF serial robot. In this method, it is aimed to evaluate joint stiffness values of any 6R serial robot using the model based on the Conservative Congruence Transformation (CCT). Pham et al. [5] proposed a method for identification of the joint stiffness values using band pass filtering. This method requires closed-loop control based on the robot’s dynamic model.

Alici and Shirinzadeh [4] presented the enhanced stiffness modeling, identification, and characterization of robot manipulators using experimental data obtained from sensors. Enhanced stiffness model is different from the conventional stiffness model which is derived firstly by Mason and Salisbury [4, 6]. While inherent stiffness of system is used in the conventional model, enhanced model contains the stiffness component due to the change in the manipulator configuration and the external forces acting on the manipulator in addition to inherent stiffness of system. The conventional stiffness model is valid only when the manipulator is in quasi-static configuration with no loading, or when it has a constant Jacobian matrix throughout its workspace [4].

Chen and Kao [7] reported that the conventional stiffness model derived by Mason and Salisbury [6] is not valid. According to them, a model based on the CCT must be used as the generalized relationship between the joint stiffness matrices and Cartesian stiffness matrices due to preserving fundamental properties of the stiffness matrices [4].

Ang and Andeen [8] presented variable passive compliance generated by means of topology of robot manipulators. As a conclusion they reported that a non-diagonal matrix is effective to prevent jamming and vibrations [4].

Abele et al. [9] presented two methods to obtain the Cartesian stiffness matrix of a 5R robot. They reported that second method is better than first because of considering the both joint and link stiffness. When load is applied, all deformations are considered such as links deformations and joint stiffness values.

This paper presents the stiffness analysis of above-knee prosthesis. The translational displacement of above knee prosthesis are obtained when the prosthesis is subjected to the external forces. Small displacements along x, y and z axes of the robot’s end-effector are illustrated by figures. Knowing stiffness values of the above knee prosthesis, researches can design prosthesis as optimal structure, height, and weight and energy consumption.

II. KINEMATIC ANALYSIS AND JACOBIAN MATRIX

A. Design of the Prosthesis

The solid model of proposed above knee prosthesis is illustrated on Figure 1. It has three joints. The first one is knee joint which is capable of one-axis movement and the second
and third one compose of ankle joint which is capable of two-axis movement.

Fig. 1. Proposed above knee prosthesis and its structure (a) knee joint (b) the entire prosthesis (c) ankle joint

B. Kinematic Model of Above Knee Prosthesis

This section deals with kinematic model of above knee prosthesis. The coordinate systems attached to the each joint of above knee prosthesis is presented in Fig. 1. The D-H parameters of the above knee prosthesis is illustrated in Table 1.

Fig. 2. The coordinate systems attached to the joint

The proposed above knee prosthesis has 3 rotational joints. The first one is knee joint which composes of one-axis movement. The second and third joints compose of ankle joint which performs two-axis movement. Ankle joint provides plantar flexion, dorsiflexion eversion and inversion movements.

The overall transformation matrix of above knee prosthesis can be written as

\[
^0T_4 = ^0T_1^1T_2^2T_3^3T_4^4
\]  

(1)

After determining D-H parameters, transformation matrices are obtained as follows.

\[
^0T_4 = \begin{bmatrix}
    c\theta_1 & -s\theta_1 & 0 & 0 \\
    s\theta_1 & c\theta_1 & 0 & 0 \\
    0 & 0 & 1 & 0 \\
    0 & 0 & 0 & 1
\end{bmatrix}
\]

(2)

The multiplication of overall transformation matrices is obtained as

\[
^0T_4 = \begin{bmatrix}
    r_{11} & r_{12} & r_{13} & p_x \\
    r_{21} & r_{22} & r_{23} & p_y \\
    r_{31} & r_{32} & r_{33} & p_z \\
    0 & 0 & 0 & 1
\end{bmatrix}
\]

(3)

where

\[
\begin{align*}
    r_{11} &= c\theta_3(c\theta_1c\theta_2 - s\theta_1s\theta_2) \\
    r_{12} &= -s\theta_3(c\theta_1c\theta_2 - s\theta_1s\theta_2) \\
    r_{13} &= c\theta_1s\theta_3 + c\theta_2s\theta_1 \\
    p_x &= l_2(c\theta_1c\theta_2 - s\theta_1s\theta_2) + l_1(c\theta_1s\theta_2 + c\theta_2s\theta_1) \\
    r_{21} &= c\theta_3(c\theta_1s\theta_2 + c\theta_2s\theta_1) \\
    r_{22} &= -s\theta_3(c\theta_1s\theta_2 + c\theta_2s\theta_1) \\
    r_{23} &= s\theta_1s\theta_2 - c\theta_1c\theta_2 \\
    p_y &= l_2(c\theta_1s\theta_2 + c\theta_2s\theta_1) - l_1(c\theta_1c\theta_2 - s\theta_1s\theta_2) \\
    r_{31} &= s\theta_3 \\
    r_{32} &= c\theta_3 \\
    r_{33} &= 0 \\
    p_z &= 0
\end{align*}
\]

(4)

The Jacobian matrix of prosthesis is obtained as follows

\[
J = \begin{bmatrix}
    -l_1s\theta_1 - l_2s(\theta_1 + \theta_2) + l_4c(\theta_1 + \theta_2) \\
    l_1c\theta_1 + l_2c(\theta_1 + \theta_2) + l_4s(\theta_1 + \theta_2) \\
    -l_2s(\theta_1 + \theta_2) + l_4c(\theta_1 + \theta_2) \\
    ... \\
    l_2c(\theta_1 + \theta_2) + l_4s(\theta_1 + \theta_2) \\
    0 \\
    0 \\
    1
\end{bmatrix}
\]

(5)
III. STIFFNESS MODELLING

The following relationship can be stated between actuated torques and the corresponding external forces and moments exerted on end-effector of the prosthesis can be expressed as:

\[ \Gamma = J^T \omega_0 \]  

(6)

where \( \Gamma \) and \( F \) are the 3x1 vectors and \( \Gamma = [\tau_1, \tau_2, \tau_3]^T \) is the actuator forces/torques needed to balance the external forces and \( \omega_0 = [f_x, f_y, f_z, f_{x0}, f_{y0}, f_{z0}]^T \) represents the corresponding external forces & moments exerted on end-effector of the prosthesis. There are two major changes happens in the manipulator because of its motion. First change happens angular position of the joints due to the torques/forges applied to the joints.

\[ \Delta = K_0 \Delta_0 \]  

(7)

where \( K_0 = \text{diag} [K_{\theta_1}, K_{\theta_2}, K_{\theta_3}] \) denotes joint stiffness matrix and \( \Delta_0 = [\Delta_{\theta_1}, \Delta_{\theta_2}, \Delta_{\theta_3}]^T \) represents change in the positions of the joints. Second change happens on the end-effector of the manipulator due to the external force and moment applied to the end-effector of the manipulator.

\[ \omega = K_\delta \Delta \]  

(8)

where \( K_\delta \) illustrates the Cartesian stiffness matrix of the manipulator and \( \Delta_0 = [\Delta_{\theta_1}, \Delta_{\theta_2}, \Delta_{\theta_3}]^T \) denotes change in the end-effector of the manipulator.

The following important identity is obtained by applying partial diffraction to the equation 1 with respect to \( \theta \).

\[ \frac{\partial \Gamma}{\partial \theta} = (J^T \partial \omega_0 + J \delta \partial X) \frac{\partial \theta}{\partial \theta} \]  

(9)

Equation 9 can be written as follows:

\[ K_\theta = K_c + J^T K_\delta J \]  

(10)

where \( K_c \) is the complementary stiffness matrix can be written for a 3DOF robotic manipulator as follows

\[ K_c = \begin{bmatrix} \frac{\partial J^T}{\partial \theta_1} & \frac{\partial J^T}{\partial \theta_2} & \frac{\partial J^T}{\partial \theta_3} \end{bmatrix} \]  

(11)

The stiffness matrix seen at the end-effector of the manipulator can be illustrated as

\[ K_\delta = J^T (K_\theta - K_c) J \]  

(12)

In order to find joint stiffness matrix, the Cartesian stiffness matrix can be simplified by ignoring \( K_c \) as follows:

\[ K_\delta = J^T K_\delta J \]  

(13)

Equation 8 can be rewritten by substituting equation 12 in equation 8 as follows.

\[ \omega = J^T K_\delta J \Delta \]  

(14)

Equation 14 can be rearranged as

\[ \Delta = K_\delta J \omega_0 \]  

(15)

Equation 15 can be rewritten as follows

\[ \Delta = \Delta_x \]  

(16)

where \( x \) and \( \Lambda \) include 6x1 vector of joint compliances and 6x6 matrix having external forces/moments and elements of Jacobian matrices.

\[ x = [1/k_{\theta_1}, 1/k_{\theta_2}, 1/k_{\theta_3}]^T \]  

(17)

IV. STIFFNESS ANALYSIS

Cartesian stiffness matrix can be obtained by using equation 11 as follows

\[ K_c = \begin{bmatrix} (-l_1 c_{\theta_1} - d_3 s_{\theta_1}) f_x + (-l_3 s_{\theta_1} + d_3 c_{\theta_1}) f_y & \cdots & c_{\theta_1} f_x + s_{\theta_1} f_y \\ 0 & \cdots & 0 \\ \vdots & \ddots & \vdots \end{bmatrix} \]  

(18)

A prosthesis end effector is forced to track a trajectory from its zero position (\( \theta_1 = \theta_2 = \theta_3 = 0 \)) to final position (\( \theta_1 = 150, \theta_2 = 15, \theta_3 = 10 \)) to identify joint stiffness values. The travel time of robot trajectory is planned as 3 seconds at 100Hz frequency. The joint stiffness values (\( K_{\theta_1}, K_{\theta_2} \) and \( K_{\theta_3} \)) along the trajectory are identified. Since trajectory frequency 100 Hz, 300 sample of joint stiffness values are obtained. The arithmetic averages of these sample values gives joint stiffness values. In this manipulator

Equation 16 can be written for prosthesis to find joint compliance values

\[ \Delta_x = \begin{bmatrix} j_{11} & j_{12} & 0 \\ j_{21} & j_{22} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1/k_{\theta_2} & 0 & 0 \\ 0 & 1/k_{\theta_2} & 0 \\ 1 & 0 & 1/k_{\theta_3} \end{bmatrix} \]  

(19)

where \( j_{11} = -l_1 s_{\theta_1} - l_2 s_{\theta_1 + \theta_2} - l_4 c_{\theta_1 + \theta_2}, j_{12} = -l_2 c_{\theta_1 + \theta_2} - l_4 c_{\theta_1 + \theta_2}, j_{21} = l_1 s_{\theta_1} + l_2 c_{\theta_1 + \theta_2} + l_4 s_{\theta_1 + \theta_2} \) and \( j_{22} = l_4 c_{\theta_1 + \theta_2} - l_3 s_{\theta_1 + \theta_2} \). This equation is reorganized to obtain 16 equality

\[ \begin{bmatrix} \delta_{\theta_1} \\ \delta_{\theta_2} \\ \delta_{\theta_3} \end{bmatrix} = \begin{bmatrix} j_{11} f_x + j_{12} f_y \\ j_{21} f_y + j_{22} f_x \\ 0 \end{bmatrix} \begin{bmatrix} f_x \\ \cdots \end{bmatrix} \begin{bmatrix} 1/k_{\theta_2} \\ 1/k_{\theta_2} \\ 1/k_{\theta_3} \end{bmatrix} \]  

(20)

V. STIFFNESS VERIFICATION

In order to compute the end effector displacements of proposed above knee prosthesis, the external forces are acted on anatomical position of human. Anatomical position is the erect position of the body with the face directed forward, the arms at the side, and the palms of the hands facing forward. It was used as a reference position for describing the relation of body parts to one another [10].

Cartesian stiffness matrix is calculated by using 12. Typical stiffness values of \( K_\theta = \text{diag} [10^5, 10^5, 10^5] \) N.mm/rad are chosen for initial values. \( K_\theta \) is constant, because it lets to the same joint stiffness values for it’s different initial values [4].
In this study, in order to have displacement values of the end-effector, an experimental study is performed. The magnitudes of force vector is implemented from 0 Newton to 200 Newton with a step size of 10 Newton as shown in Table II.

<table>
<thead>
<tr>
<th>Force Vector ( (F_x, F_y, F_z) ) (Newton)</th>
<th>Deflection Calculated</th>
<th>( \delta_x ) (mm)</th>
<th>( \delta_y ) (mm)</th>
<th>( \delta_z ) (mm)</th>
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<tbody>
<tr>
<td>0,0,0</td>
<td></td>
<td>0</td>
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</tr>
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<td>0,00003655</td>
<td>0,00005472</td>
<td>0,00001</td>
</tr>
<tr>
<td>20,20,20</td>
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<td>0,0001094</td>
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<tr>
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<tr>
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<td>0,0008</td>
<td>0,014</td>
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<td></td>
<td>0,0007</td>
<td>0,0011</td>
<td>0,002</td>
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</tbody>
</table>

Fig. 3 represents the deflection values along the x, y and z-exes of prosthesis end-effector under the forces exerted on the prosthesis as shown in Table 2.

VI. CONCLUSION

In this study, the stiffness analysis of the proposed above-knee prosthesis is presented. The translational displacement of above knee prosthesis are obtained when the prosthesis is subjected to the external forces from 0 Newton to 200 Newton with a step size 10 Newton. The computed displacements along x, y and z axes of the prosthesis’s end-effector are illustrated by a table and figures. These results can be used to design and
manufacture an above knee prosthesis. Results can also help researchers to choose the material which will be used.

REFERENCES


A Visual Stimulus Module for P300 Based Brain Computer Interfaces

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Abstract—Brain Computer Interfaces (BCIs) are the systems that provide a direct communication channel between human brain and environment. P300 potentials are involuntary brain responses which are used to control BCI systems. In order to elicit P300 responses, stimulus presentation must be provided to the users. However, there are not a common paradigm or optimal parameters for all BCI users, or all BCI applications. Using the most convenient method and parameters for each user individually will improve system performance. This study proposes a visual stimulus module for P300 based BCIs. The module offers to design stimulus interfaces based on three different stimulus interfaces, including row/column, single character and region based paradigms. The module also provides customization of the stimulus interface by setting optimal parameters for individuals practically. Furthermore, in this study, we also explained synchronization between stimulus interface and data acquisition module in detailed. In order to test the stimulus module, stimulus interfaces based on three visual stimulus paradigms were designed. All the paradigms were tested by three subjects. P300 responses yielded with three paradigms were compared by using one-way statistical analysis of variance (ANOVA) method. Preliminary results revealed that average amplitude and latency of P300 potentials that were elicited by the different paradigms may differ.

Keywords—Brain Computer Interface (BCI), P300 Potentials, Visual Stimulus Module, Row/Column Paradigm, Single Character Paradigm, Region Based Paradigm

I. INTRODUCTION

Neuromuscular diseases, such as amyotrophic lateral sclerosis, brainstem stroke, brain or spinal cord injuries, cerebral palsy, muscular dystrophy, multiple sclerosis etc. cause damage on the muscles or nerves that control the muscles, and lead to loss of voluntary muscle movements. Over 100 million people worldwide are affected by these diseases. Brain Computer Interfaces (BCIs) are systems that enable people with neuromuscular diseases to interact with external world without using neuromuscular activity. In other words, BCIs detect the signal activity in the brain and translate the changes in the brain activity into the control commands directly [1-3].

P300 potentials of event-related potentials (ERPs) is one of the electrophysiological signals used in BCI studies. P300 potentials are involuntary brain responses appeared in approximately 300 ms after an infrequent and task relevant stimulus is presented to the subject [4]. In order to elicit P300 potentials in EEG signal, stimulus presentation must be provided. According to user’s preferences and level of the disease, the stimulus presentation can be visual [4], auditory [5] or tactile [6]. However, superior performances were yielded by studies that use visual stimulus. [5].

Stimulus presentation in P300 based BCIs is based on oddball paradigm principle [7]. In oddball paradigm, during the stimulus presentation, all the stimuli intensify randomly. Meanwhile, users are asked to distinguish the two stimuli categories: target stimulus (task relevant infrequent stimulus) and non-target (irrelevant) stimulus, i.e. to focus on the target stimulus, and to count intensifications of each target stimulus silently. Intensification of target stimulus elicits P300 potential in EEG signal. Oddball paradigm is firstly adapted to the BCI studies as row/column paradigm for spelling applications [4]. Then, several visual stimulus paradigms based on oddball principle are proposed [8-10]. All these paradigms have their own advantages and disadvantages (Table 1).

Features of P300 potentials and performance of P300 based BCI systems vary according to the stimulus paradigm [11] and parameters of the stimulus interface [12-18], as well as individual characteristics of subjects, such as gender and age [19-20]. Stimulus and background colors, stimulation type, number of sequences, and stimulus timing can be listed as stimulus interface based factors. Colors of the stimulus interface are one of the factors that affects on system performance. Ikegami et.al. [12], revealed that character and background colors of visual stimulus interface affect the target prediction accuracy of the BCI system on both healthy and disabled subjects. Besides, Takanoa et.al. [13] is revealed that using soft colors increases the performance of the system. Stimulation type is another factor of the stimulus interfaces. Visual stimulation can be provided by changing one or more properties of an item on the matrix, such as position, angle, pattern rotation or size. There is not a stimulus type that can be defined as the most successful for all subjects, however it is also revealed that selection of user specific stimulus type increases information transfer rates as well as accuracy [14-15]. During the stimulus presentation, number of sequences is another important factor on BCI system performance. Because P300 potential amplitude is very low, higher character prediction accuracy cannot be accessed by using small number of sequences. Despite the fact that increasing the number of sequences improves the target character prediction accuracy, it also causes to lower the bit rate. Number of sequences varies according to the level of attention and concentration of the subjects and is a selectable parameter for synchronous BCI
applications [16]. On the other hand, there is not a consensus on effects of interstimulus interval on classification accuracy yet. Although high target character prediction accuracy is achieved by using longer interstimulus interval by Farwell and Donchin [4], high classification accuracy is obtained using short interstimulus interval by Meinicke et.al [17] and also Seller et.al [18]. A module that enables BCI operators to easily set up these parameters facilitate the stimulus interface design process. Furthermore, BCI operators easily customize stimulus paradigms for the use in numerous comparative analysis.

There are several BCI platforms that provide an easy way for designing a BCI system [21]. These platforms are generally specialized on a specific paradigm such as row/column paradigm for P300 based applications. However, according to the user preferences or the application to be controlled, privatization of the stimulus paradigm may be needed. Selection of visual stimulus paradigm and optimization of BCI system parameters for each user individually enables to achieve the best system performance [18].

In this study, a general-purpose visual stimulus module that enables the selection of visual stimulus paradigms and specific parameters is designed for P300-based BCIs. The designed stimulus module contains three different paradigms including row/column paradigm, single character paradigm and region based paradigm. The module also provides to set the parameters such as stimulus type, analyze type, stimulus timing, stimulus and background colors practically and offers an easy way for comparative studies that investigates the effects of various paradigms and parameters to P300 responses. Preliminary tests of the designed module carried out on three paradigms with the participation of three subjects.

The rest of the paper is organized as follows: Section II is a brief explanation of the visual stimulus paradigms which are included in the stimulus module. The visual stimulus module that is designed in this study is introduced in Section III. Then, experimental design is presented in Section IV. Experimental results are presented in Section V. Finally, Section VI concludes the paper.

II. VISUAL STIMULUS PARADIGMS

A. Row/Column Paradigm

Row / column (RC) paradigm was developed by Farwell and Donchin [4] and has been used in many studies. In this paradigm, letters, numbers or commands are placed so as to form the elements of a matrix. Stimuli are presented by intensification of rows or columns on matrix randomly. In case of using a matrix of 6x6, stimulus interface contains 12 stimuli, and consists of 6 rows and 6 columns. Row and column that contain target character are grouped as the target stimuli and remaining 10 rows and columns on the matrix are grouped as non-target stimuli. The matrix used in this paradigm contains 36 characters and because of giving stimulus as rows and columns, target probability is 1/6 [4].

B. Single Character Paradigm

Single character (SC) paradigm is designed by Guan et.al.[8]. The idea behind the design of this paradigm is that P300 amplitude is inversely proportional to target probability. In single character paradigm, stimuli are given by intensification of each character in the matrix individually [8]. In this way, in case of using a matrix of 6x6, probability of eliciting P300 potential is reduced to 1/36. However, assuming that number of sequences are equal, compared to the row/column paradigm, single character paradigm requires three times longer operating time for selecting a character. This paradigm is preferred especially for control applications that use icons, words or characters which are in different size at the same stimulus interface [22].

C. Region Based Paradigm

Region based (RB) paradigm is designed for reduction of perceptual error resources that are encountered in matrix based paradigms, such as row/column and single character paradigms [23]. In this paradigm, characters are grouped in several regions instead of rows or columns of a matrix. Stimulus presentation and the character selection processes are achieved in two levels. After selecting the target region at the first level, characters of the selected region are shown on the screen. At the second level, characters of the selected group flash individually. Subject concentrates on a particular character on the screen and the final target character is selected [24].

Region based paradigm may increase the number of characters that are used in stimulus interface by increasing the number of nested levels. It also ensures lower oddball probability as in row/column paradigm (In this study, because of using 7 regions, oddball probability is 1/7). Besides, the paradigm provides reduction of crowded effect and adjacency errors [25].

<table>
<thead>
<tr>
<th>TABLE I: COMPARISON OF P300 BASED VISUAL STIMULUS PARADIGMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PARADIGM</strong></td>
</tr>
<tr>
<td><strong>Advantage</strong></td>
</tr>
<tr>
<td><strong>Disadvantage</strong></td>
</tr>
<tr>
<td><strong>Target Probability</strong></td>
</tr>
<tr>
<td><strong>Time for Selection of a Character</strong></td>
</tr>
<tr>
<td><strong>ISI</strong>: Interstimulus interval</td>
</tr>
</tbody>
</table>
III. VISUAL STIMULUS MODULE

In this study, we designed a visual stimulus module for P300 based BCI studies. The module provides to customize stimulus interface by selecting paradigms and specific parameters. As well as the other BCI operations of the BCI system, such as data acquisition and signal processing and classification, stimulus interface is also designed by using Matlab. The designed visual stimulus module is given at Figure 1. The module includes three different stimulus paradigms for both online and offline applications. Details of the module is as given below.

Analysis Type: There are two types of data recording and analysis methods: offline and online.

Offline Analysis: Offline analysis is the method that signal processing, classification and character prediction procedures are performed after data recording procedure.

Online Analysis: In online analysis, signal processing, classification and character prediction procedures are performed simultaneously with data recording.

Paradigms: The module enables to create three visual stimulus paradigms: row/column paradigm, single character paradigm and region based paradigm.

Row/Column Paradigm: Stimulus are given by intensification of rows and columns in the matrix.

Single Character Paradigm: Stimulus are the random intensifications of each characters on the matrix individually.

Region Based Paradigm: Stimulus are grouped on several regions. Stimulus are given by intensification of the regions individually. Character selection procedure requires a two-level process.

Stimulus Type: Stimulus type is another parameter of the module. Changing size, color, thickness or both of size and color of the stimulus are stimulus types that can be applicable by the module.

Number of Sequences: Number of sequences defines the number of intensification of each items on the screen. Number of sequences affects the time required to select a character and also affects information transfer rate of the system. Although the number of sequences is a selectable parameter for synchronize online application, asynchronous online applications are independent from number of sequences.

Target Characters: The target character option is used for determination of character prediction accuracy by comparing the target and predicted characters after analysis are completed. On the other hand, target characters are used to give feedback for online sessions.

Stimulus Timing: Timing of a stimulus sequence is a widely investigated criterion on P300 based BCIs. The stimulus module enables to set all timing details of a stimulus sequences.

Stimulus Duration: This period defines the intensification duration of a stimulus.

Interstimulus Interval (ISI): Interstimulus interval is the time interval between two consecutive intensifications.

New Character and Feedback Interval: It is a time period to inform user that a new selection will start. At this period, all of the stimulus on the stimulus interface are intensified together in order to inform subjects that the cycle for the previous character has been completed and a new cycle for a new character is going to start. This interval is also important for resting of the subjects. Moreover, in online applications, the intended character is determined and also feedback is provided to the users during this period.

Colors: Both characters on the matrix and background color of the matrix can be changed according to user preferences and experimental setup.

Outputs of the Visual Stimulus Module: After the analysis type, paradigm and parameters are selected, stimulus interface is run by the BCI operator. The stimulus sequences are generated randomly. In order to reduce perceptual error sources, during the stimulus presentation, consecutive presentation of the same stimulus, i.e. cell, region or row/column is prevented.

Figure 2a and 2b represent the row/column paradigm and single character paradigm interfaces respectively. In this study, for row/column paradigm and single character paradigm, interfaces are designed for spelling applications. In Figure 2, character color and size are the stimulus types for both paradigms. Figure 2c and 2d represent the stimulus interfaces for region based paradigm. Region based paradigm is designed for environmental control applications and figures related to the commands are used as stimulus. Figure 2c is the first level of the stimulus interface and Figure 2d is the second level of the first region on the first level.

At the end of the stimulus presentation, program automatically creates three files to keep stimulus indexes, EEG signal, and selected parameters. Stimulus file contains
stimulus indexes that generated randomly by the program. Signal file contains raw EEG data recorded on several channels. All the parameters used during data recording are also saved in a file named parameters.

**Synchronization:** At BCI applications, simultaneous recording of EEG data and stimulus indexes is quite important in terms of accurate determination of the timing of P300 responses. Therefore, the prepared stimulus module interacts with the EEG device directly during data recording and transfers randomly generated stimulus codes to the EEG device. In this way, EEG data can be recorded with stimulus indexes simultaneously and P300 responses in EEG data can be divided exactly. In this study, 16 channel V-amp biosignal amplifier (Brain Products GmbH) is used for recording EEG signal. Synchronization is provided by sending trigger signals to the device through the LPT (Line Printer Terminal) port. Trigger signals consists of device connection code, run of stimulus interface code, new character code, stimulus codes of each character, completion code of a run.

**IV. Experiments**

In order to validate the visual stimulus module, we set up the stimulus paradigms by using the module. All the three interfaces were tested on healthy subjects. The study was approved by the ethics committee of Faculty of Medicine, Gazi University. Three subjects participated voluntarily in the experiments. None of the participants had P300 based BCI experience before. All of the participants were male and the mean age of the participants was 27. EEG signal was recorded on Cz position with an active electrode. The reference and ground electrodes were placed at right earlobe and AFz respectively. All the electrode impedances were kept below 10kΩ.

Three different experimental setups, including row/column, single character and region based paradigms, were established by using the designed stimulus module. The subjects were asked to select 4 items at each three sessions which are designed with different paradigms. The number of sequences was 15, stimulus duration was 150ms and interstimulus interval was 300ms for all paradigms. Therefore, total time for selection of a character was 15*12*300ms =54s for row/column paradigm, 15*36*300ms=162s for single character paradigm and 15*2*7*300ms=63s for region based paradigm.

The EEG signals were recorded with V-amp amplifier (Brain Products GmbH) at a sampling rate of 250 Hz. EEG signals were segmented 1s time windows after each stimulus onset. Segmented EEG signal was filtered at 5 Hz by a 5th order Butterworth lowpass filter. Grand average ERP waveform of target responses was yielded by averaging the EEG signal.

Statistical analyses were carried out using the SPSS 15.0. One-way statistical analysis of variance (ANOVA) was carried out for determining difference of amplitude and latency among the paradigms. A p-value <0.05 was considered as statistical significance level.

**V. Results and Discussion**

In this section, we present the preliminary results of the designed visual stimulus module. Subjects were asked to select four characters by using the three stimulus interfaces which were established by the visual stimulus module. P300 waveform of a character was obtained by averaging the EEG signal for all three stimulus paradigms individually.

As an illustration, averaged P300 potentials that were obtained from Subject 1 at electrode location Cz by using the three different visual stimulus paradigms are seen in Figure 4. As seen from the Figure 4, all of the paradigms created P300 responses with different properties on the same subject. Maximum amplitudes of P300 responses were 1.68 μV, 4.27 μV and 2.35 μV, and P300 latencies were 492 ms, 496 ms and 620 ms for row/ column, single character and region based paradigms respectively. The highest P300 amplitude was achieved in case of using single character paradigm. The preliminary results confirmed the theory that smaller oddball probability may elicit higher P300 amplitude.
In order to determine whether or not P300 amplitude and latency differ among the paradigms, one-way statistical analysis of variance (ANOVA) test was carried out on three subjects. The analysis of P300 peak amplitude revealed a significant difference among the paradigms \( F=47.66, p=0.00 \). Table 2 shows the \( p \) values for Bonferroni post hoc test that was used for pairwise comparison of the paradigms. According to the results, RC paradigm is significantly different from SC paradigm \( (p=0.000) \) and RB paradigm \( (p=0.025) \). On the other hand, SC paradigm is also significantly different from RB paradigm \( (p=0.000) \) in terms of maximum P300 amplitude. The results revealed that P300 amplitude was elicited in the different paradigms were significantly different from each other.

Average P300 peak latencies were 443 ms for RC paradigm, 514 ms for SC paradigm, 604 ms for RB paradigm. The test results revealed a significant difference \( F=28.62, p=0.000 \) among the paradigms in terms of latency. Bonferroni test results also revealed that there were significant differences between the paradigms RC-SC \( (p=0.026) \), RC-RB \( (p=0.000) \) and SC-RB \( (p=0.007) \). According to the preliminary results, although the signal was recorded under the same conditions, amplitude and latency of P300 potential that was elicited in the different paradigms may vary.

Table 2 shows the \( p \) values for Bonferroni post hoc test of averaged peak amplitudes/latencies for the three visual stimulus paradigms.

<table>
<thead>
<tr>
<th>Peak Amplitudes</th>
<th>Latencies</th>
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<tbody>
<tr>
<td>RC</td>
<td>SC</td>
</tr>
<tr>
<td>RC</td>
<td>-</td>
</tr>
<tr>
<td>SC</td>
<td>0.000</td>
</tr>
<tr>
<td>RB</td>
<td>0.025</td>
</tr>
</tbody>
</table>

RC: Row/Column Paradigm, SC: Single Character Paradigm, RB: Region Based Paradigm

VI. CONCLUSION

There is not a common paradigm or parameters that can be accepted as the most successful to elicit P300 potentials for all BCI users. The most optimal paradigms or related parameters differ between both healthy and disabled subjects, even among healthy subjects. Besides, a stimulus paradigm that can be considered as the most suitable for all BCI application is not identified. In this study, we designed a visual stimulus module for P300-based BCI applications. The stimulus module offers to design three P-300 based stimulus paradigms and to set specific parameters. Selecting subject-specific paradigm and parameters would provide subjects to achieve a higher classification and target prediction success in real time applications. Since it provides a common platform for different stimulus paradigm presentation, the designed module is especially useful for comparative experimental studies.

Although this module is designed for spelling and control applications currently, it is possible to adapt the stimulus interfaces to a variety of applications by replacing characters and symbols on the stimulus screens easily. In the future, new stimulus paradigms will be reproduced and the module will be enriched in terms of stimulus paradigms. Besides, the module will be improved by addition of signal processing and classification tools. In this way, the module will also offer operators the opportunities to analyze the raw EEG signal, practically.

ACKNOWLEDGMENT

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Pulse Oximeter Manufacturing & Wireless Telemetry for Ventilation Oxygen Support

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Abstract—Pulse Oximeter devices are widely used as a non-invasive method for instant monitoring of blood oxygen saturation and heart rate. In this paper, a wireless microcontroller based pulse oximeter is proposed to measure the oxygen delivered to the patient via the oxygen flowmeter. In the first step, the signals received from reusable SpO₂ sensor (finger probe) are processed by a microcontroller to determine the blood oxygen saturation and heart rate. Depending on the current blood oxygen saturation value, wireless signals are sent to the non-invasive ventilation flow meter vacuum regulator to deliver the necessary oxygen into the patient. Oxygen supplied to the patient is automatically controlled according to the oxygen saturation change.

Keywords—Pulse Oximeter, Oxygen saturation, Ventilation, Oxygen flow meter, Oxygen regulator, Circuit design, Wireless control.

I. INTRODUCTION

Oxygen is the common drug to be used in the care of patients who present with medical emergencies. Currently, ambulance and emergency department teams are likely to give oxygen to all breathless a large number of patients [1].

The amount of oxygen saturated hemoglobin in arterial blood is expressed with oxygen saturation [2]. Formerly, the most common method of assessing oxygenation was the use of arterial blood gases [3]. This is painful for patients and has the serious complications of vascular injury or occlusion and infection. The methods of applying also pose the risk of needle stick injury to staff [4].

Today, pulse oximetry is a safe and simple method of assessing oxygenation [2]. At the same time, they are cheap and easy to carry devices. Pulse oximeter is a measuring device as peripheral arterial oxygen saturation in the blood non-invasively. Pulse oximeter shown in Figure 1, can be monitored from bedside monitors as used alone. Pulse oximeter is required intraoperatively monitors. During patient monitoring using pulse oximeters the early detection of untoward events is the most important, especially as it may contribute to the prevention of hypoxic insults [5].

Pulse oximetry is a routine device used in surgery, intensive care units and operating rooms, due to its cheapness. It is a non-invasive device and easy to be used. [6].

Oxygen flowmeter illustrated in Figure 2 is used to give the oxygen to the patient through the humidifier, nose nozzle and mask. Vacuum regulator allows patients to adjust the vacuum level. It has the manometer to see visually the pressure. Vacuum regulator is set manually as shown in figure 2.

The patient may need to be supported by mechanical ventilation when the respiratory system fails [7]. Mechanical ventilation is common form of life support in the intensive care unit (ICU) [8]. Although mechanical ventilation is one of the ultimate life-supporting technologies, in recent years, there has been renewed interest in the injury that it can cause. The concept that high airway pressures during positive pressure ventilation can cause gross injury manifest has been well known and investigated for a long time [9]. It was found that an average of 40% of the patients died in the process of finalizing mechanical ventilation. It was found that also a high overall mortality in the intensive care unit [10].

In the literature, there have been several studies on pulse oximetry. Although the small number of wireless applications, studies involving with oxygen flow meter have not been a part of literature. Some of the studies in the literature on pulse oximetry and wireless communications are as follows: Watthanawisuth and his team (2010) worked on the monitoring of pulse oximetry with wireless wearable system [11]. Qing Cai, Jiming Sun, Ling Xia ve Xingqu Zhao (2011), have created a wireless pulse oximeter sensor using a wrist strap [12]. Turban and Niwayama (2011) have worked on reducing the power consumption of wireless pulse oximeter [13]. Rekha Chandra, Safer and Srividya (2015) worked on the development and miniaturization of wireless pulse oximeter [14]. Render, frosty and Dalkılıç (2014) worked based on the Arduino Healthduino wireless Mobile Health Monitoring System, cloud-based database, doctors and patients mobile applications [15]. In the study by using RF technology. Adochie and colleagues wireless pulse oximeter is designed. Also it has been monitored with WiFi or GSM / GPRS technology [16].

The studies mentioned above do not both measure oxygen saturation and supply oxygen automatically to the patients. The aim of this study is to design a system that measure first the oxygen saturation and provide the required oxygen to the paints via a wireless and mechanical ventilation system. For this purpose, a microcontroller is used to measure the blood oxygen saturation. A wireless signal including the measured blood oxygen saturation data is sent to the non-invasive ventilation flow meter vacuum regulator to deliver the required oxygen into the patient. This process is repeated as the doctor's recommendation continues. Thus, according to symptomatic status of the patient, mechanical ventilation causing pre-intervention to acute respiratory failure is no mere required. By using proposed device in this study, O₂ saturation can be
precisely arranged and delivered to the patients. Microcontroller programming with proper protocols based on the different patient stories and different diseases can prevent the problems caused by human influences.

![Figure 1: Pulse oximeter.](image1)

Figure 1: Pulse oximeter.

Figure 2: Oxygen Flowmeter, Vacuum regulator.

II. PULSE OXIMETRY

Respiratory system is specialized to allow gas exchange between ambient air and blood. The 97% part of oxygen composes of chemical compounds with the hemoglobin in the red blood cell and rest of 3% composes of dissolved in the fluid plasma and cells. Oxygen saturation is defined as the ratio of hemoglobin to total hemoglobin bound to oxygen in the blood.

The O₂ saturation is close to 100% under normal conditions. The O₂ saturation between 97% and 100% represents good gas exchange within the person. Hypoxia is mentioned above when SpO₂ level falls below 90% and may require respiratory support. Identifying hypoxia conditions in an early stage is important. Thus an early intervention becomes possible and therapy starts immediately.

According to the blood gas analysis method, ‘arterial oxygen saturation’ is represented by the symbol SaO₂ in the literature. This parameter corresponds to the oximetry method ‘arterial oxyhemoglobin concentration’ (represented by the measured SpO₂ symbol). The main difference between SaO₂ and SpO₂ parameters is that SpO₂ presents the amount of oxygen bound to the hemoglobin molecule found while SaO₂ denotes the total amount of oxygen in the arteries [17].

Oximeters are devices that determine the oxygen concentration of various species of Hb [18].

A. PRINCIPLES OF PULSE OXIMETER

Light is transmitted, absorbed, or reflected when it passes through matter. The relative absorption or reflection of light at different wavelengths is used in several monitoring devices to estimate the concentrations of dissolved substances. This type of measurement is called spectrophotometry and is based on the Beer-Lambert Law. According to the Beer-Lambert Law, if a known intensity of light illuminates a chamber of known dimensions, then the concentration of a dissolved substance can be determined if the incident and transmitted light intensity is measured [18].

The pulse oximetry is based on two physical principles. The first one is the light absorbance of oxygenated hemoglobin and the second one is the absorbance at different wavelengths with pulsatile (AC) component [19]. Pulse oximeter is based on the principles to absorb light different level by oxygenated hemoglobin with reduced hemoglobin [14].

The form of Hb is important issue. In the adult blood usually contains four species of Hb: HbO₂, reduced Hb, methemoglobin (metHb), and carboxyhemoglobin (COHb). Each of Hb species has a different light absorption profile. The different absorption constants for each Hb species over a range of light from red to infrared are shown in Figure 3 [18].

Pulse oximetry uses the wavelengths of 660 nm and 940 nm because these wavelengths are available in semiconductors. The oximeters measure red and infrared light transmitted through and reflected by a tissue bed. There are several technical problems to accurate estimation of SaO₂ by this method. For example, many light absorbers other than arterial Hb are in the transmitted light path (e.g., skin, soft tissue, venous). A group of absorbers in a typical sample of living tissue is shown in Figure 4 [18].

![Figure 3: Hemoglobin extinction curves](image2)

Figure 3: Hemoglobin extinction curves

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The AC component represents absorption of light by the pulsating arterial blood at the top of the figure. The DC (baseline) component represents absorption of light by the tissue layer. The pulse oximeters mostly use only two wavelengths of light, typically 660 nm (red light) and 940 nm (infrared light). The pulse oximeter first determines the fluctuating or AC component of absorbance at two wavelengths. Secondly it divides this value by the DC component to obtain the pulse-added absorbance which is independent of the incident light intensity. Thus, the oximeter then calculates the ratio (R) of the two pulse-added absorbance (one for each wavelength) [19]:

\[
R = \frac{AC_{660}/DC_{660}}{AC_{940}/DC_{940}}
\]  

(1)

Pulse oximetry is calibrated using the calculated value of R. An example of a pulse oximeter calibration curve is shown in Figure 5 [22].

The attenuation characteristics of light passing through the fingertip consist of three components: tissue loss, and (vein) the weakening of the artery (artery) attenuation. Tissue attenuation and veins attenuation have a constant characteristic. Arteries (arterial) blood flow in fingertip causes light attenuation variation. The reason is the change in the oxygen saturation of the blood pumped to the body blow to the heart of each pulse. Heart rate (pulse) signal is superimposed on the fixed component which is weakening. Thus, arterial oxygen saturation can be calculated by subtracting from the total attenuation of the attenuation constant and vein tissue attenuation components [17].

The SpO₂ value can be read incorrectly in some situations, environmental effects, and technical. These conditions are:

- Very bright light in the operating room (such as more lighting).
- Abnormalities in value of carboxyhemoglobin and methemoglobin.
- Electrocautery device can be prevented by transportation of signal to diode when it running.
- It may be affected by light emitted from the surgical light in the hall.

SpO₂ value cannot be measured or read incorrectly when the patient's fingernails very long, fingernails with diamonds, henna, dyed and so on.

III. PULSE OXIMETER MANUFACTURING AND WIRELESS TELEMETRY FOR VENTILATION OXYGEN SUPPORT

In this study, a telemetry control system is proposed to support oxygen to the patients based to the data measured by pulse oximeter. The schematic diagram of proposed wireless telemetry system for ventilation oxygen support with pulse oximeter is shown in Figure 7.
A. PULSE OXIMETER MANUFACTURING

The pulse oximeter block diagram in Figure 7 is illustrated in Figure 8 in detail. Pulse oximeter is proposed to design using microcontroller.

It consists of a photodiode and two LEDs including red and infrared LEDs. The $\text{SpO}_2$ sensor LEDs are connected as shown in Figure 9. The LEDs are controlled by the microcontroller PWM signal. However, the microcontroller PWM output cannot provide enough power to drive properly led. LEDs are forced to give enough energy by the led driver circuit. A finger probe measures the oxygen saturation via pulse oximeter probe as analog signal. Since the only one photodetector for the two LED signals, the signals cannot be received at the receiver at the same time, thus requiring switching of signals. Double the switching drive integrated, red and infrared LEDs with two signals from the microcontroller does turn on and off. The timing diagram to drive the LEDs is shown in Figure 10.

Photodiode generates an analog current depending on the light absorption. This current must turn into voltage. That transformation is performed in analog signal conditioning circuit. The analog signal conditioning circuit is illustrated as in Figure 11.

The $\%\text{SpO}_2$ is calculated when the signal is applied to Analog-Digital Converter (ADC) module in microcontrollers. Signal conditioning circuit consists of three stages. First stage is amplifier (transimpedance amplifier), which takes a few micro-amps current by photodiode and turning into a few millivolts. Transimpedance amplifier is an amplifier as well as current-voltage converter. The signal passes by High Pass Filter (HPF). Therefore background light interference is reduced. High Pass Filter output is upgraded with second stage gain amplifier.

There are two filter applications. The first one is a passive RC filter illustrated within a circle in Figure 11. The second one is in the microcontroller as software. The digital filter is called FIR. Microcontroller include Digital Signal Processing (DSP) unit. DSP performs digital Finite Impulse Response (FIR) that is the filtered data. FIR is a software filter. The filtered data is used to calculate the pulse amplitude. The pulse amplitude is used to calculate $\text{SpO}_2$ and heart rate.

Finally microcontroller sends the computed data about blood oxygen saturation to the second microcontroller via wireless unit.
B. WIRELESS OXYGEN FLOWMETER CONTROL

Flowmeter manually operate in general. In this study it is operated automatic control with a motor and motor driver circuit. It uses pulse oximeter wireless data for automatic control.

1) OXYGEN SUPPLY AND EQUIPMENT

Oxygen is supplied for patients from two sources, including central system and O₂ tubing. Flowmeter (oxygen flow measuring equipment) and humidifier (humidification oxygen canister) is located in the patients unit. It is shown in Figure 2.

The pressure in the oxygen tube is very high to provide oxygen to the patient. The pressure to be used medically appropriate level (40-70 psi-pounds) must be reduced. Therefore, regulator is used in order to regulate the pressure. Regulator is an arranger by display.

Flowmeter adjusts the flow rate per minute of oxygen delivered to the patient. Humidifier is a chamber used depending flowmeter. It allows the moisture of the oxygen from the oxygen source.

In patients with respiratory; nasal cannula, simple face mask, partial mask recycled, recyclable mask, nebulizer mask and oxygen header methods are used. In patients without respiratory mask balloon system (Bannings valve-mask) is used. [14].

2) MOTOR CONTROL CIRCUIT

In this application, a motor is mounted on the flowmeter. The data is taken from a pulse oximeter with wireless communication module.

The motor control system is shown in figure 12. This system provides motor control with wireless data from pulse oximeter. It is controlled motor speed and left-right rotation by implementation of the appropriate voltage values.

\[ \text{motor} = K_1 * A_1 + K_0 * A_0 \]

Equation 2 is used for to determine motor speed.

K₀ and K₁ expressions in the equation 2 are coefficients used to determine the applied voltage to the motor according to the received value.

If the pulse oximeter measurement SpO₂ value falls under %95, then the motor works. If it falls under %90 then the oxygen transferred to the patient is increased. If the measurement value rise above 95%, then rotation reversed valve is closed.

Motor situation and SpO₂ values can be changed easily in the microcontroller. Thus working system can be programmable according to doctor’s protocol.

IV. RESULTS

Developments in electronics and sensor technology yields several advantages for biomedical applications. For example, analog and digital devices for bio-signal treatment can easily be employed by microcontrollers.

Biosensors and pulse oximeter probes can be the candidate subject for different researches. The conventional analogue probes are required to be updated. Instead of these instruments, it is possible to develop better digital probes.

This study has not been finalized yet. The pulse oximeter telemetry system presented in this study is cheap, fast, easy to use & setup and medical risks low example. The mechanical ventilation risks for using hypoxia control were explained. Furthermore mechanical ventilation devices are very expensive. The manual flowmeter using simple oxygen support is not enough for hypoxia control. This application eliminates both drawbacks of applications.

This study leads to some other studies such a new design of pulse oximeter that decrease the heat and other pigments effect, a new device that adjusts blood pressure, bilirubin, cholesterol, glucose levels and hemoglobin counter.

V. REFERENCES


Evaluation Of The Compound Muscle Action Potential In Diagnosis Of The Mild Carpal Tunnel Syndrome

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Abstract— Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy. In most patients, the diagnosis can be proposed based on patient history and clinical symptoms, with electrophysiological findings. The mild CTS may not produce any nerve conduction abnormalities and this can make standard conventional tests not enough in diagnosis the mild CTS. The aim of this study was to evaluate Compound Muscle Action Potential (CMAP) morphology as more sensitive and specific parameters without any additional testing for diagnosis the mild CTS. A total of 77 clinically diagnosed patients with CTS were prospectively enrolled. Data was evaluated from 70 normal hands and 46 hands with the diagnosis of the mild CTS with standard electrophysiological (EDX) tests and clinical findings. The specificity and sensitivity rate were calculated to evaluate the utility of CMAP negative peak (NP) morphology parameters evaluated duration (CMAP NPHalf-Duration) and area (CMAP NPHalf-Area and CMAP NPFull-Area) by comparing the standard EDX test (Median Distal Motor Latency (DML) and peak to peak amplitude of CMAP (CMAP NPAmplitude) recorded from the abductor pollicis brevis (APB) muscle. Although CMAP NPHalf-Duration and CMAP NPFull-Duration had no statistically significantly difference between the mild CTS and normal group (p>0.05), DML, CMAP NPAmplitude, CMAP NPHalf-Area and CMAP NPFull-Area in the mild CTS group were statistically significantly different (p<0.05). The present study shown that CMAP NPFull-Area had the highest sensitivity and moderate specificity rate (90.0% and 42.2%, respectively). Furthermore, it was confirmed again that DML was a valuable motor nerve conduction technique for the diagnosis of the mild CTS with high sensitivity and moderate specificity (84.8% and 84.8%, respectively), and it had more sensitive than CMAP NPHalf-Area high sensitivity and moderate specificity (80.0% and 38.7%, respectively). This study provided the evidence of CMAP NPFull-Area and CMAP NPHalf-Area that could be predictors of the mild CTS.

Keywords— carpal tunnel syndrome, motor nerve conduction study, clinical electromyography, signal processing

I. INTRODUCTION

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy caused by median nerve compression at the wrist causing pain, paresthesia, and functional problems [1]. Its prevalence ranges from 1-5% in the general population [2]. CTS is diagnosed on the basis of clinical signs and symptoms and is confirmed by an electro diagnostic (EDX) tests. Nerve conduction study (NCS) and electromyography (EMG) are a standard part of the evaluation for CTS. They are useful to support the diagnosis of CTS, to assess severity, to provide a baseline for postoperative assessment in patients with unsatisfactory surgical result, and to exclude other abnormalities such as polyneuropathy, myopathy and radiculopathy [3]. The EDX tests rest upon the demonstration of impaired median nerve conduction across the carpal tunnel in the context of normal conduction elsewhere. Nerve compression results in damage to the myelin sheath and manifests as delayed distal latencies and slowed conduction velocities with resulting in a reduction of the median nerve compound motor action potential amplitude (CMAP) or sensory action potential amplitude (SNAP). Several EDX techniques have been established as standard and conventional methods for diagnose of CTS [4-5]. Although NCS and EDX tests have been widely used in diagnosing CTS, there are still ongoing debates particularly on accurate because sensitivities of EDX tests have ranged between 49% and 84% with specificities of 95% or higher. Furthermore, EDX test may have a substantial rate of false-negative findings, and so rely instead on clinical findings, especially in mild CTS that may not produce any nerve conduction abnormalities [6-9]. The patients have signs and symptoms of CTS, but the conventional studies may show equivocal or false negative. On the other hand, there are patients with median slowing at the wrists but who do not have CTS. Consequently, the main point of contradiction is that EDX tests yield negative results on symptomatic persons or positive results on no symptomatic persons [10].
signs) were performed before the EDX tests. The patients who had electrical evidence of CTS and patients with suspected clinically CTS but no EDX was used in the diagnosis of mild CTS. And then we compared these parameter’s sensitivity in the mild CTS.

It is generally accepted that median sensory conduction is more sensitive than motor conduction in the EDX of CTS. However, the low sensitivity of standard median motor EDX techniques in detecting motor axon abnormality also needs to be considered [13]. CMAP results from the sum of all the synchronously activated muscle fiber action potentials generated through all the axon destined to the APB muscle. The CMAP is an indirect measurement of the number of axons that conduct between the stimulating and recording points. A change in the CMAP emerges in peripheral nerve disorders. It is most prominent in entrapment neuropathies and demyelinating neuropathy, in which conduction is either blocked or delayed because of segmental demyelination [14]. Although distal CMAP duration prolongation is useful diagnostic tool for chronic inflammatory demyelinating polyneuropathies (CIDPs), the parameters analysed of the morphology of the distal CMAP can be also potentially useful parameters in the diagnosis of the mild CTS. In this manner, it cannot be needed significantly more time-consuming conventional EDX techniques which the patient can refuse extensive testing because of poor tolerance to electrical stimulation.

The aim of this study was to evaluate diagnostic value of the half-duration and the full-duration of CMAP negative peak (NP) and the half-area and the full-area of CMAP NP as a complementary test in diagnosis of mild CTS. And then we compared these parameter’s sensitivity and specificity with both DML and CMAP amplitude obtained conventional EDX tests.

II. METHODOLOGY

A. Study Group

A total 77 subjects (25 female, 5 male) with suspected CTS was retrospectively enrolled in Gazi University Faculty of Medicine between January 2014 and December 2014. After EDX tests in EMG Laboratory, 70 normal hands belonging to patients with suspected clinically CTS but no electrophysiological evidence of CTS and 46 symptomatic hands belonging to patients with mild CTS were included in the present study.

Physical examination consisted of evaluating of muscular strength, sensory function and provocative clinical test (Tinel signs) were performed before the EDX tests. The patients who have numbness, tingling pain, or paresthesia in the median nerve distribution, and have precipitation of these symptoms by repetitive hand activities and relieved by resting, rubbing, and shaking the hand were included. The patients who have history or clinical signs suggesting systemic disease such as double-crush injury, diabetes, chronic renal failure, gout, rheumatoid arthritis, thyroid diseases and have clinical or electrophysiological signs suggesting pathological conditions such as myelopathy, polynuropathy, radioculopathy, myopathy were excluded. We selected only the mild CTS diagnosed according to the criteria of our laboratory and used for diagnosis and classifying of the CTS [15-16].

B. Electrophysiological Measurements

A Medelec Synergy EMG device (Medelec, Surrey, UK) was used in the study. Filters were set at 20 Hz and 2 kHz for motor studies. Stimulation was supramaximal and sensitivity was 1 ms. The sweep speed was set at 1 ms/division and sensitivity was selected as 20 µV/division. Cup electrodes (Ag-CI) were used for motor NCVs. In the NCVs, the distance between the recording electrodes is 3-5 cm. The active electrode was over the endplate region of the main bulk of the APB muscle innervated by the nerve being tested in order to obtain the maximal response with no initial positivity. The reference electrode was over the tendon of the muscle. The ground electrode was placed on the between the stimulating and recording electrodes providing a zero voltage reference point. Electrical stimuli were delivered by a constant current stimulator through bipolar surface electrodes. The distance between two felts is 3 cm and the diameter of the electrodes is 8 mm. It was applied supramaximal for a period of 0.1-0.5 ms and approximately and in a density of 10-30 mA. Skin temperatures were continuously monitored and maintained between 32–34°C during the procedures and the room temperature was maintained between at 22°C and 25°C.

1) Motor NCS: DML was recorded with a distance of 5 cm between the stimulation point of the nerves at the wrist and the APB muscles. DML was measured from the stimulus onset to the initial negative response, and the CMAP amplitude was measured from baseline to negative peak and measured in millivolts (mV), shown in Figure 1. Markers which indicated the onset, negative peak, positive peak and end of the CMAP waveforms were automatically determined by the Medelec Synergy software. In case of incorrectly placed, markers were manually repositioned.

2) CMAP Morphology: As shown in Fig.1, CMAP NP full-duration was measured from initial deflection from baseline (1) to the first baseline crossing (3). CMAP NP half-duration was measured from initial deflection from baseline (1) to the peak point on negative peak (2). The calculation of half-duration might be more accurate. Because full-duration of CMAP NP might return to baseline very slowly. In addition, CMAP NP half-area and CMAP NP full-area were calculated.

3) Signal Analyses: All CMAP duration and area measurements were manually marked and calculated by Signal5 Software (CED, micro1401, Camridge, UK). Using this software, CMAP signals were full-rectified and compared.
peak and baseline markers with not rectified original signal. Because a baseline shift or other electrical interference may lead to a problem for reliable measure of the area. The terminal positive deflection of the CMAP having multiple baseline crossings and phases was not calculated in the measurement because the end of the repolarization phase was frequently difficult and complex to determine [14,18].

Fig. 1 Components of the Compound muscle action potential (CMAP) [17].

C. Statistical Analyses

The mean and standard deviations were calculated for statistical analysis using SPSS 20.1 (The Statistical Package for Social Sciences, Chicago, IL, USA). The two-tailed Student’s t-test was used for comparative statistics. In order to assess the differences (age and gender) between the normal control group and the abnormal group, Chi-square test was performed. For the statistical significance, the probability level of 5% (p ≤ 0.005) was preferred.

Validity was assessed by the ability of CMAP amplitude, duration and area to discriminate between the mild CTS and the control groups using area under the receiver operator characteristic curve (ROC). The ROC curve was obtained by plotting the sensitivity of all possible cut-off points for a test on the y-axis against ‘1-specificity’ (false positivity) on the x-axis. As a measure of the overall performance of a diagnostic test, the area under the ROC curve (AUC) was estimated using a form of the trapezoid method, and 95% confidence interval of the AUC was estimated by the bootstrap method approach. Accuracy was measured by the area under the ROC curve. One criterion for evaluating the cut-off point of a test was to maximize the sum of sensitivity and specificity. It was thought of optimally better cut-off for differentiating patients. It is known that searching for a more sensitive test might present the drawback of decreased specificity, leading to false positives [19]. It was considered cut-off points for both high sensitivity and high specificity.

III. RESULTS

Totally 77 subjects with CTS suspicion were clinically examined with conventional EDX methods in EMG laboratory. While total 29 subjects (25 women (86.2%) and 4 men (13.8%), age = 55.14±7.5) were diagnosed as the mild, total 48 subjects (39 women (81.2%) and 9 men (18.8%), age= 41.62±13.8) were assessed with normal findings. Totally 116 hands (70 normal hands and 46 asymptomatic hands) belong to subjects were included in this study. The characteristic of study population is given in Table 1.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Subjects N (%)</th>
<th>Age (mean±SD)</th>
<th>Total N (%)</th>
<th>Age (mean±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>F 39 (81.2)</td>
<td>40.8±12.6</td>
<td>48 (62.3)</td>
<td>41.6±13.8</td>
</tr>
<tr>
<td>Mild CTS</td>
<td>M 9 (18.8)</td>
<td>45.1±18.8</td>
<td>29 (37.7)</td>
<td>55.1±7.5</td>
</tr>
<tr>
<td>CTS</td>
<td>M 4 (13.8)</td>
<td>52.7±5.8</td>
<td>29 (37.7)</td>
<td>55.1±7.5</td>
</tr>
<tr>
<td>Total</td>
<td>F 64 (83.1)</td>
<td>46.5±13.1</td>
<td>77 (100)</td>
<td>46.7±13.5</td>
</tr>
</tbody>
</table>

CTS= carpal tunnel syndrome, F= female, M=male, N=number, SD=standard deviation

The comparison of the diagnostic competence of the parameters in terms of mean value, sensitivity, specificity and AUC are shown Table 2.

TABLE II Comparisons of parameters between the control and the mild CTS groups.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control (mean±SD)</th>
<th>Mild CTS (mean±SD)</th>
<th>p</th>
<th>Cut-off value</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>DML (ms)</td>
<td>2.91 ± 0.3</td>
<td>3.40 ± 0.3</td>
<td>0.000</td>
<td>≥ 6.8</td>
<td>84.8</td>
<td>47.6</td>
<td>0.800</td>
</tr>
<tr>
<td>CMAP amplitude (mV)</td>
<td>14.66 ± 3.4</td>
<td>11.07 ± 3.5</td>
<td>0.000</td>
<td>≤ 11.0</td>
<td>80.0</td>
<td>36.5</td>
<td>0.766</td>
</tr>
<tr>
<td>CMAP NPt duration (ms)</td>
<td>4.9 ± 0.0</td>
<td>4.7 ± 0.0</td>
<td>0.331</td>
<td>≥ 4.5</td>
<td>65.7</td>
<td>13.5</td>
<td>0.560</td>
</tr>
<tr>
<td>CMAP NPt latency (ms)</td>
<td>10.5 ± 0.0</td>
<td>10.2 ± 0.0</td>
<td>0.208</td>
<td>≥ 9.8</td>
<td>56.5</td>
<td>12.1</td>
<td>0.572</td>
</tr>
<tr>
<td>CMAP NPt_area (mVms)</td>
<td>26.5 ± 0.0</td>
<td>20.6 ± 0.0</td>
<td>0.000</td>
<td>≤ 20.5</td>
<td>80.0</td>
<td>38.7</td>
<td>0.727</td>
</tr>
<tr>
<td>CMAP NPt_area (mVms)</td>
<td>60.8 ± 0.0</td>
<td>45.5 ± 0.0</td>
<td>0.000</td>
<td>≤ 41.9</td>
<td>90.0</td>
<td>42.2</td>
<td>0.743</td>
</tr>
</tbody>
</table>

DML = distal motor latency, CMAP = compound muscle action potential; NP= negative peak; ms= milisecond; mV=mili volt; SD= standard deviation; p= statistical significance value; AUC= area under curve. 

DML significantly differed between groups. There was statistically significant difference in terms of CMAP NPPt.Area and CMAP NPt.Area between the mild CTS and control group (P<0.001). However, there was no significant difference between the control and mild CTS groups.
in terms of CMAP NP\textsubscript{Half\_Duration} and CMAP NP\textsubscript{Full\_Duration} between groups (P=0.331 and P=0.208, respectively).

In the diagnosis of mild CTS, CMAP NP\textsubscript{Half\_Area} parameter (cut-off ≤ 41.9, 90.0% sensitivity and 42.2% specificity) had the highest sensitivity and second high specificity rates. DML parameter (cut-off ≥ 6.82, 84.8% sensitivity and 47.6% specificity) had the highest specificity and second high sensitivity rates. Although CMAP\textsubscript{Amplitude} (cut-off ≤ 11.00, 80.0% sensitivity and 36.5% specificity) and CMAP NP\textsubscript{Half\_Area} (cut-off ≤ 20.5, 80.0% sensitivity and 38.7% specificity) parameters showed similarly high sensitivity and specificity rates, Both of CMAP NP\textsubscript{Half\_Duration} and CMAP NP\textsubscript{Full\_Duration} parameters had similarly the lowest sensitivity and specificity rates.

AUC values of DML (AUC = 0.800, 95% CI), CMAP\textsubscript{Amplitude} (AUC 0.766, 95% CI), CMAP NP\textsubscript{Half\_Area} (AUC = 0.727, 95% CI) and CMAP NP\textsubscript{Full\_Area} (AUC = 0.753, 95% CI) parameters having a “good” ratio were significantly different from 0.5 and that therefore it was considered that these parameters had an ability to distinguish between the mild CTS and healthy subjects. However, it was found that both of CMAP NP\textsubscript{Half\_Duration} (AUC = 0.560, 95% CI) and CMAP NP\textsubscript{Full\_Duration} (AUC = 0.572, 95% CI) parameters having a “fail” rate had no ability of the test to correctly classify those with and without the mild CTS. ROC curves belong to all parameters is shown in Figure 3.

![ROC curves](image-url)

**Fig. 2** ROC curves (a) MDL (b) CMAP\textsubscript{amplitude} (c) CMAP NP\textsubscript{half\_duration} (d) CMAP NP\textsubscript{full\_duration} (e) CMAP NP\textsubscript{half\_area}, and (f) CMAP NP\textsubscript{full\_area}

**IV. DISCUSSION**

The major finding of this study there were significant differences in the all the CMAP amplitudes, DML, CMAP\textsubscript{Amplitudes}, NP\textsubscript{Half\_Area} and CMAP NP\textsubscript{Full\_Area} between the mild CTS and normal control groups. This result on stimulating at the wrist may be an manifestation of axonal loss, conduction block or a combination. In the mild CTS, the primary abnormality observed with EDX measures was conduction slowing, which represents focal demyelination. Whereas distal latencies can reflect nerve conduction slowing of the fastest fibers. CMAP duration can depend on temporal dispersion among the distal motor fibers. On the other hand, some factors such as the distribution of conduction velocities of individual axons within the nerve, the distance between stimulating and recording electrodes, the morphology of each single-fiber action potential and phase cancellation between individual single-fiber action potentials also might have influenced CMAP morphology and in particular CMAP duration.

Ginanneschi et al. found similar results of the sensitivity of wrist-to-APB motor conduction studies using submaximal stimulus intensities. Padua et al. claimed that CMAP\textsubscript{Amplitude} was decreased only in patients with severe CTS as a result of the loss of motor units [15]. On contrary this, we found that CMAP\textsubscript{Amplitude} was not decreased only in patients with severe...
CTS as a result of the loss of motor units but also in mild CTS. Unlike our finding, Nashed et al. found that there was no difference in peak-to-peak MUAP amplitude between the mild CTS and the control groups [20]. It can be result in due to their very small study group (9 control group and 8 mild CTS)

In many previous studies, CMAP NP full-duration prolongation assessed by measuring NP is commonly used in CIDP as diagnostic parameter [21-24]. CMAP duration prolongation can be rare in conditions that lead to distal latency prolongation in CTS. But we found that CMAP NP full-duration prolongation has not been incorporated in the diagnostic criteria for mild CTS. Similarly, Cleland et al. found that, in contrast to CIDP, dispersion of the median CMAP was uncommon, even in advanced carpal tunnel syndrome, being seen in only 8 of 103 (7.8%) hands [18]. Isose et al., in comparison of CMAP duration between normal controls and CTS patients, found very low sensitivity (for cut-off =5.8 ms., 23% sensitivity and for cut-off = 6.6 ms, 12% sensitivity) like our results [25].

The significant difference shown in NP full and half area may be considered as a manifestation of a very mild affection of motor axonal loss in even the mild CTS cases which are accepted as normal in terms of motor fibers involvement regarding the classification. Similar findings were found in DML which is also in normal range in mild cases. The classification suggests to evaluate cases as moderate when the DML is abnormal (prolonged as compared with the normal limits).

V. LIMITATIONS

The main limitation of our study was the lack of sufficient and reliable cut-off values for CMAP duration, amplitude and area. Larger studies are needed to confirm the reference range of CMAP with diagnostic studies including larger sample sizes and well-defined study groups. Because cut-off values can be influenced by the choice of patients with axonal loss in the control group.

Other limitation of our study is the control group who were referred to the ENMG laboratory with the suspicion of CTS. Some of these patients might be very mild cases in whom the electrodiagnostic tests are normal. Therefore allocation of control subjects who are also clinically normal would be more valuable to detect milder differences.

VI. CONCLUSIONS

In mild CTS, motor fibres can be more often affected than was originally thought and CMAP area also can reflect the number of muscle fibers in the CMAP. In this regard, we suggest distal CMAP area would be added into one of the EDX criteria for mild CTS in addition to conventional motor NCS. For further studies, it can be evaluated with new studies comprising large study groups and patient groups in different stages of CTS and including SNAP parameters (e.g., duration, area and amplitude) as well as wrist-elbow motor NCS including CMAP parameters (e.g., duration, area and amplitude).

REFERENCES


Feature Selection on MR Images using Genetic Algorithm with SVM and Naive Bayes Classifiers

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Abstract—Dementias are termed as neuropsychiatric disorders. Brain images of dementia patients can be obtained through magnetic resonance imaging systems. The relevant disease can be diagnosed by examining critical regions of those images. Certain brain characteristics such as the cortical volume, the thickness, and the surface area may vary among dementia types. These attributes can be expressed as numerical values using image processing techniques. In this study, the dataset involves T1 medical image sets of 63 samples. Each particular sample is labeled with one of the three dementia types: Alzheimer's disease, frontotemporal dementia, and vascular dementia. The image sets are processed to create different feature groups. These are cortical volumes, gray volumes, surface areas, and thickness averages. The main objective is seeking brain sections more effective in establishing the clinical diagnosis. In other words, searching an optimal feature subset process is carried out for each feature group. To that end, a wrapper feature selection technique namely genetic algorithm is used with Naive Bayes classifier and support vector machines. The test phase is performed by using 10-fold cross validation. Consequently, accuracy results up to 93.7% with different classifiers and feature selection parameters are shown.

Keywords— Genetic algorithm, Feature selection, Dementia, Classification, Magnetic resonance imaging.

I. INTRODUCTION

Dementia diseases are termed as neuropsychiatric disorders, and encounter rate of them increases severely with age [1]. Brains of patients with dementia denote several differences in some ways such as cortical volume, thickness, surface area, according to disease type. The most common three dementia types may be sorted as Alzheimer’s disease (AD), vascular dementia (VaD) and frontotemporal dementia (FTD) respectively. In neuroimaging science, an unknown diagnosis is tried to be determined via medical images. Magnetic resonance imaging (MRI) is a technique interprets the anatomy. The T1 pulse sequence is one of the basic sequences in MRI that achieving remarkable tissue contrast and provides a good correlation when larger amounts of iron are present [2]. 2-dimensional brain images in slices can be acquired with MRI. These sliced output files have digital imaging and communications in medicine (dicom) file extension frequently, and project brain to a particular axis. Besides, aforementioned files contain patient information. It is possible to reach measurements of brain regions using those medical imaging files with image processing techniques. In theory, unknown diseases can be labeled with the aid of classification algorithms taking numerical expressions of brain sections as input parameters. Meanwhile, some features may be qualified as more precious.

In the beginning of this research, some classification tests were performed with taking all extracted brain features as input set. The accuracy results were not satisfying at all. Therefore, finding the lowest size feature set having high precision classification result constitutes the motivation of the study. Briefly in this study, samples with three dementia types are tested to seek a valuable feature subset with genetic algorithm (GA) based wrapper feature selection method over different classification algorithms.

A. Literature Review

When it comes to the literature research of interdisciplinary brain imaging studies, there are numerous indicative papers. The number of the studies using free-access datasets such as Alzheimer’s Disease Neuroimaging Initiative (ADNI), AddNeuroMed, etc. is quite high. The number of the studies using their own dataset is also a great deal more. In addition, some software tools are utilized for operations such as the construction of the virtual brain, feature extraction, etc. in computer science studies.

In 2011, Freesurfer v4.5.0 brain analyzing software tool was used for analyzing the brains of 295 AD, 444 mild cognitive impairment (MCI), 335 control subjects from the ADNI database. 23 regional volume and 34 cortical thickness features for 1074 MRI scans were used for the orthogonal partial least squares (OPLS) classification [3]. In another research, the performance of different methods through several brain regions was compared upon the features obtained from T1 MRI scans after the Freesurfer process.

509 AD, MCI or elderly control individuals aged between 55 and 90 from ADNI database were processed. Features were extracted and grouped as voxel-based (grey matter, white matter and cerebrospinal fluid in given voxel), vertex-based (the features are defined on the cortical surface) or...
In neuroimaging science studies, software tools used often as exemplified in the literature section. In this work, FreeSurfer v5.3.0 was used for medical image processing and analysis. FreeSurfer is a functional, connectional and structural human brain analyzing tool that comprises a set of image processing, numeric, etc. algorithms [8]. In a few words, the tool associates sliced medical imaging files structurally with the help of header information. Later on, the virtual 3-dimensional brain is modeled by following image processing techniques iteratively. For each individual samples, the same procedure is repeated. Working principle of

### II. Dataset

The dataset used in this research belongs to the picture archiving communication systems (PACS) of Eskişehir Os mangazi University’s Radiology Department.

The set consists of 63 dementia patients namely AD, FTD and VaD. Each sample is labeled only with one of these three clinical diagnoses. Samples are either male or female and ages of them vary between 50 and 90. Image sets were obtained from *Discovery MR750w* (GE, Milwaukee) and *Magnetom Vision plus* (Siemens, Erlangen) MRI systems last 2 years. Counts of dementia types over genders and MRI systems are shown in Table I.

<table>
<thead>
<tr>
<th>Dementia Type</th>
<th>Male</th>
<th>Female</th>
<th>Discovery MR750w</th>
<th>Magnetom Vision plus</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD</td>
<td>5</td>
<td>14</td>
<td>13</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>FTD</td>
<td>6</td>
<td>13</td>
<td>13</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>VaD</td>
<td>12</td>
<td>13</td>
<td>17</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>40</td>
<td>43</td>
<td>20</td>
<td>63</td>
</tr>
</tbody>
</table>

In this work, T1 weighted image sets are used. Each sliced T1 weighted scan has MR modality and 2-dimensional MR acquisition type. Slice thicknesses of all image sets are between 4.5-5 millimeters. Also, all images are grayscale at least $256 \times 256$ image resolution and have dicom file extension.

### III. Methodology

The basic idea of this study is achieving the optimal feature subset having the highest accuracy. The method incorporates several consecutive operations. T1 weighted image sets, obtained from brain imaging studies via MRI systems, are preprocessed with brain modeling software. Freesurfer brain analyzing tool is used for preprocessing the sliced medical images and feature extraction from the virtual brain. After then, feature matrices in different measurements are created. Feature selection algorithm is applied to each feature group separately to determine the subset having high classification accuracy result. For this purpose, GA based wrapper feature selection algorithm over different classifiers is performed.

Tools and algorithms mentioned in the following subsections are put into practice to obtain results.

#### A. Feature Extraction

In neuroimaging science studies, software tools used often as exemplified in the literature section. In this work, FreeSurfer v5.3.0 was used for medical image processing and analysis. FreeSurfer is a functional, connectional and structural human brain analyzing tool that comprises a set of image processing, numeric, etc. algorithms [8]. In a few words, the tool associates sliced medical imaging files structurally with the help of header information. Later on, the virtual 3-dimensional brain is modeled by following image processing techniques iteratively. For each individual samples, the same procedure is repeated. Working principle of

### B. Paper Organization

In Section 1, an introduction to the research and literature review are presented. In Section 2, the dataset is described. In Section 3, the methodology of this research is explained, additionally in subsections, feature extraction, classification, feature selection, and testing methods are noticed succinctly. In the following section, tests and results are reported. Finally in the last section, the conclusion is made and feature plans are mentioned.
Freesurfer can be summarized as three major steps basically. Firstly, correction and verification operations for input files are processed. Secondly, volumetric registrations, removing neck actions, white matter segmentations, and also some visual smoothing transactions occur at this step. At the end of the last step, containing spherical instructions followed by cortical parcellation, brain modeling is completed [9], [10]. During the procedure, data is transferred the way that the output of each sub-step will be the input of another step, analysis process continues gradually. When the procedure is completed with success, visual and statistical files become accessible. Depending on computer hardware, the entire Freesurfer process described may take quite some time. In 2011, Cuignet et al. reported that a single Freesurfer modeling could take roughly a day [4]. Likewise in 2012, Gronenschild et al. uttered that this whole process found to be completed in 30 hours and what is more, analysis may be affected by tool versions or operating system differences [11]. In this research, Freesurfer operations over T1 medical images were executed with a computer having Intel®Core™i7-4700 2.40 GHz CPU, 1600 MHz 16 GB RAM hardware, and Ubuntu 14.04 x64 operating system. Multiple Freesurfer processes run parallelly for groups of samples. In detail, 3-dimensional modeling of brain structure for each sample was accomplished at the end of approximately 15 hours time period. No manual editing was used after analysis.

In the Literature Review section, some of the significant features are listed. Accordingly, from the Freesurfer statistics files, cortical volume features for whole brain structure, moreover, gray volume, surface area and thickness average features for left and right parts of the brain are taken into consideration in this study. Values are exported via bash scripts. Lastly, each feature is normalized to a length of 1 while creating feature matrices.

B. Classifiers

1) Naive Bayes Classifier: Characteristics for each class are thought independently. Theoretically, features are supposed to be uncorrelated by implementing the Bayes’ rule with naive independence assumptions. Conditional probabilities are estimated for all classes. The sample, whose class label is unknown, is labeled with the name of the class having maximum probability [12]. NB (Naive Bayes) method is also known as a conditional classifier.

2) Support Vector Machines: SVM is based on the methodology of perceptron algorithm. The principle of SVM is searching for a line that separates the plane into two classes. With using kernel functions, the algorithm tries to maximize the distance between the optimal hyperplane and nearest support vectors [13]. Furthermore, one to all strategy may be preferred for multi-class problems in like manner. This algorithm is also known as a maximum margin classifier.

C. Feature Selection

In classification studies, when all features are used as inputs, the input set may contain insignificant features and consistent results may not be achieved. Classification results can be enhanced using the worthwhile feature subset. In this work, GA was used for eliminating insignificant features from whole feature set. The principle of the algorithm is based on the disappearance of weak genes by natural selection and survival of the best ones evolving from one generation to another during biological adaptation [14], [15]. In mathematical approach, GA searches an optimal solution for a problem from one set to another. In the methodology, the solution comes from a set of numerical values namely chromosomes. Populations are configured to any constant size and contain a set of various chromosomes. A fitness function is needed to compute the cost when a particular chromosome is selected for a possible solution to a problem. This function calculates the fitness cost of each chromosome in the population. Finding an optimal solution is performed in generation cycles. In each generation, the search is directed toward finding the best solution until then. The algorithm transfers better chromosomes to build new generation population iteratively. Sometimes, elites having the best fitness are preferred to be placed in new generation directly. Likewise, reproduction functions such as crossover, selection, mutation, are used for creating next generations. Crossover function produces two child chromosomes that are synthesized by parents. Selection function describes which individuals are chosen for the next level. Mutation function changes chromosome parts randomly [14], [16]. In this study, the main objective of using GA is seeking an optimal feature subset by wrapper feature selection approach via classification accuracy for selected chromosome. Chromosomes specify which features are paid attention to in bit strings. In other words, chromosomes act like selection masks. Related bit indices in the living chromosome, that are equal to 1, are entitled to be in the sub-feature set. After then, feature subset takes place as the input of fitness cost function. From this point of view, the fitness cost function is defined as the accuracy result of the selected features in the classification process.

D. Cross Validation

k-fold cross validation technique carries out to compute overall classification performance. k-fold cross validation term implies that (1/k)th of the whole dataset is chosen as a test set, and the rest is chosen as a train set automatically for all k rounds. It is ensured that each sample becomes a test sample just once. In this study, before GA was implemented, the dataset had been partitioned into 10-folds randomly. Each test run started with the same folds. Classification performances were based on 10-fold cross-validation for NB & SVM classifiers. Eventually, test performances are reported as the percentage of correctly classified cells in confusion matrices.
IV. Tests and Results

The testing phase proceeded in two different ways. According to the number of input classes, 3-Class and 2-Class GA based wrapper feature selection tests over NB and SVM classifiers were performed. In 3-Class tests, for each feature group, best feature subsets that classify all dementia types were found. To put it another way, the whole dataset was analyzed. Also in 2-Class tests, features that separate particular dementia type from other types with high classification accuracy results were examined. In other words, these tests were performed as one versus the others. For both tests, some GA parameters were set distinctly in order to arrange operation time considering the input class count.

GA parameters of 3-Class tests were chosen as: 10% for elite count, 90% for crossover fraction. Roulette selection function, single point crossover function and uniform mutation function with 13% rate created new generations. 3-Class (AD, FTD, VaD) classification tests performed over NB classifier with 800 for population size and initial population was created randomly in bit sting chromosome type. Algorithm worked with maximum 1000 generations. With given parameters, genetic algorithm results of 3-Class tests are shown in Table I.

Before the 2-Class tests began, samples, that did not belong to the examined class, were labeled as others (Oth). For each dementia type, this procedure was repeated. Afterwards, GA parameters of 2-Class tests were chosen as: 10% for elite count, 90% for crossover fraction. Roulette selection function, single point crossover function and uniform mutation function with 13% rate created new generations. 2-Class (AD v Others, FTD v Others, VaD v Others) classification tests performed over NB and SVM classifiers with 400 for population size and initial population was created randomly in bit sting chromosome type. Algorithm worked with maximum 500 generations. With given parameters, genetic algorithm results of 2-Class tests with NB and SVM are shown in Table III and Table IV respectively.

TABLE II
3-Class Genetic Algorithm Results with Naive Bayes Classifier

<table>
<thead>
<tr>
<th>Feature Group</th>
<th>Total Feature Count</th>
<th>Best Feature Subset Count</th>
<th>Acc %</th>
<th>Confusion Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical Volumes</td>
<td>41</td>
<td>17</td>
<td>84.1</td>
<td>[17 0 2; 1 16 2; 2 3 20]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Gray Volumes</td>
<td>34</td>
<td>17</td>
<td>69.8</td>
<td>[10 5 4; 0 1 18 1; 4 5 16]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Left Surface Area</td>
<td>34</td>
<td>16</td>
<td>74.6</td>
<td>[11 5 3; 1 14 4; 2 1 22]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Thickness Average</td>
<td>34</td>
<td>11</td>
<td>69.8</td>
<td>[11 2 6; 4 11 4; 3 0 22]</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Right Gray Volumes</td>
<td>34</td>
<td>16</td>
<td>71.4</td>
<td>[7 4 8; 0 16 3; 0 3 22]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Surface Area</td>
<td>34</td>
<td>17</td>
<td>63.5</td>
<td>[10 8 1; 4 12 3; 4 3 18]</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Right Thickness Average</td>
<td>34</td>
<td>9</td>
<td>73</td>
<td>[11 1 7; 1 14 4; 2 2 21]</td>
</tr>
</tbody>
</table>

TABLE III
2-Class Genetic Algorithm Results with Naive Bayes Classifier

<table>
<thead>
<tr>
<th>Feature Group</th>
<th>Total Feature Count</th>
<th>Classes</th>
<th>Best Feature Subset Count</th>
<th>Acc %</th>
<th>Confusion Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical Volumes</td>
<td>41</td>
<td>AD v Oth</td>
<td>18</td>
<td>92.1</td>
<td>[18 14 40]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
<td>17</td>
<td>90.5</td>
<td>[16 3 41]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>24</td>
<td>87.3</td>
<td>[21 4 38]</td>
</tr>
<tr>
<td>Left Gray Volumes</td>
<td>34</td>
<td>AD v Oth</td>
<td>18</td>
<td>88.9</td>
<td>[16 3 40]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
<td>17</td>
<td>90.5</td>
<td>[19 6 38]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>11</td>
<td>88.9</td>
<td>[20 5 30]</td>
</tr>
<tr>
<td>Left Surface Area</td>
<td>34</td>
<td>AD v Oth</td>
<td>17</td>
<td>79.4</td>
<td>[22 7 38]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
<td>17</td>
<td>88.9</td>
<td>[4 5 42]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>10</td>
<td>88.9</td>
<td>[19 6 37]</td>
</tr>
<tr>
<td>Left Thickness Average</td>
<td>34</td>
<td>AD v Oth</td>
<td>18</td>
<td>88.9</td>
<td>[16 3 40]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
<td>17</td>
<td>85.4</td>
<td>[14 5 40]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>23</td>
<td>82.5</td>
<td>[16 9 30]</td>
</tr>
<tr>
<td>Right Gray Volumes</td>
<td>34</td>
<td>AD v Oth</td>
<td>17</td>
<td>81</td>
<td>[16 3 35]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
<td>16</td>
<td>81</td>
<td>[10 2 42]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>23</td>
<td>81</td>
<td>[16 9 35]</td>
</tr>
<tr>
<td>Right Surface Area</td>
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<td>AD v Oth</td>
<td>18</td>
<td>93.7</td>
<td>[17 2 42]</td>
</tr>
<tr>
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<td></td>
<td>FTD v Oth</td>
<td>16</td>
<td>82.5</td>
<td>[10 9 42]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>13</td>
<td>79.4</td>
<td>[13 12 37]</td>
</tr>
<tr>
<td>Right Thickness Average</td>
<td>34</td>
<td>AD v Oth</td>
<td>18</td>
<td>88.9</td>
<td>[14 5 42]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
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<td>87.5</td>
<td>[17 2 42]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>23</td>
<td>82.5</td>
<td>[18 7 34]</td>
</tr>
</tbody>
</table>

When all test results are analyzed, feature subsets having significant classification accuracies are found. Also, subset findings are in smaller sizes than the input matrices. In classifier comparison, NB performs slightly better than SVM for 2-Class tests.

Cortical volume features are striking to the eyes as the most significant feature group. In addition to the groups, behind the confusion matrices and best feature subset counts, valuable features are observed as left lateral ventricle, left putamen, brain-stem, left vessel, right cerebellum white matter, right putamen and 5th ventricle. Moreover, left thalamus proper, left pallidum, 3rd ventricle, 4th ventricle, left choroid plexus, right lateral ventricle, right caudate, right amygdala, right ventralis, white matter hypointensities and optic chiasma may also be included to the list as the secondary valuable.
TABLE IV
2-CLASS GENETIC ALGORITHM RESULTS WITH SUPPORT VECTOR MACHINES

<table>
<thead>
<tr>
<th>Feature Group</th>
<th>Total Feature Count</th>
<th>Classes</th>
<th>Best Feat. Subset Count</th>
<th>Acc %</th>
<th>Confusion Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cortical Volumes</td>
<td>41</td>
<td>AD v Oth</td>
<td>10</td>
<td>82.5</td>
<td>[8 11 0 44]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
<td>9</td>
<td>82.5</td>
<td>[8 11 0 44]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>9</td>
<td>90.5</td>
<td>[19 6 0 38]</td>
</tr>
<tr>
<td>Left Gray Volumes</td>
<td>34</td>
<td>AD v Oth</td>
<td>7</td>
<td>88.9</td>
<td>[13 6 1 43]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
<td>11</td>
<td>82.5</td>
<td>[8 11 0 44]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>10</td>
<td>85.7</td>
<td>[17 8 1 37]</td>
</tr>
<tr>
<td>Left Surface Area</td>
<td>34</td>
<td>AD v Oth</td>
<td>8</td>
<td>82.5</td>
<td>[14 7 4 40]</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FTD v Oth</td>
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<td>82.5</td>
<td>[8 11 0 44]</td>
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<tr>
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<td>VaD v Oth</td>
<td>10</td>
<td>82.5</td>
<td>[14 11 0 38]</td>
</tr>
<tr>
<td>Left Thickness Average</td>
<td>34</td>
<td>AD v Oth</td>
<td>11</td>
<td>85.7</td>
<td>[10 9 0 44]</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>8</td>
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<td>[9 10 1 43]</td>
</tr>
<tr>
<td></td>
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<td>VaD v Oth</td>
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<td>7.08</td>
<td>[15 10 2 54]</td>
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<tr>
<td>Right Gray Volumes</td>
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<td>FTD v Oth</td>
<td>12</td>
<td>81</td>
<td>[7 12 0 30]</td>
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<tr>
<td>Right Surface Area</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>VaD v Oth</td>
<td>10</td>
<td>79.4</td>
<td>[15 10 3 35]</td>
</tr>
</tbody>
</table>

V. CONCLUSION

In neuroimaging science, comparing classification results among different researches may not be straightforward due to attributes of each dataset like sample size, disease types, etc. Additionally, image preprocessing algorithms for feature extraction step, and also testing phase parameters may affect the classification performance. These issues have been reported in some researches previously [4], [5]. Therefore, the consistency of the work within itself may become much more considerable. In this work, a wrapper feature selection approach through certain classifiers with specific consistency of the work within itself may become reported in some researches previously [4], [5]. Therefore, the effects of freesurfer version, workstation type, and macintosh operating system version on anatomical volume and cortical thickness measurements,” PloS one, vol. 7, no. 6, pp. e38234, 2012.


SMART DEVICES BASED REMOTE PATIENT MONITORING SYSTEM

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Abstract— Nowadays, smart devices have become an indispensable part of our lives with the advancement of technology. Developments of wireless and technology have led to the emergence of innovation providing facilities and solutions to the problems in health care. With developing technology, measured parameters can monitor on smart devices which required to follow in the diagnosis and treatment process of chronic illness and diseases. For example for this studies, remote monitoring of blood glucose level for diabetes patients or remote monitoring of blood pressure for patients. In this study, the smart device based remote patient monitoring system realized using microcontroller and Wi-Fi module. Vital parameters are measured over patients such as blood pressure, pulse, body temperature. Moreover, ambient moisture and temperature values are determined by device. The measured parameters are recorded on the device and the parameters are transmitted to the experts via web-based mobile interfaces. With this work, physiological parameters of the patients can be measured in their current location. Consequently, patients will be able to follow parameters without requesting help from health personnel’s on real time. Moreover, they can send their parameters to expert people.

Keywords—Remote patient monitoring, telemedicine, smart devices

I. INTRODUCTION

Rapidly advancing technological developments lead to radical changes in the health sector. In this context, new concepts and applications have been emerging such as telemedicine, e-health, e-prescribing, electronic health records, smart card in health sector. Telemedicine which is defined as the concept of using communication technologies among people from a distance for diagnosis, treatment and follow-up in order to forward the physiological data, storage and delivery of healthcare is closed to this study [1].

Some factors that cause the spread of telemedicine applications;
- increase in the cost of health care due to the increase in population,
- need to reduce patients in the hospital,
- effective utilization requests of doctors,
- it can be determined in a more effective treatment with the achievement of long-term statistics about the disease.

Also usage of telemedicine can be divided as remote patient monitoring, diagnosis and treatment of disease, medical education, and research [2]. Ministry of Health carried out many e-health projects using progressive technology and intelligent system [3].

Health sector has serious problems due to growing and aging world population and also significant increase in the number of chronic patient. So, technological developments and intelligent systems have been used extensively in the health sector in order to resolve these issues and find out solutions. Nowadays, smart devices have become an indispensable part of our lives and are used extensively. In this context, independent of time and distance in the field of health wireless technology and sensors have been used effectively for monitoring and storing patient's physiological data from anywhere with convenient storage solutions. In the field of health, remote patient monitoring concept have emerged. This concept is especially beneficial for bed-ridden patients or those having difficulty to reach a doctor. Another benefit of this concept is that it reduces the density of the number of patients coming to the hospital. Thus, the applications of smart devices in the field of health provide the possibility to send the necessary vital data to experts regardless of the location of patients [4].

In the literature, remote patient monitoring and telemedicine areas have been studied quite extensively. Chettri has to work based on smart phones with patient tracking and wireless data communication system in order to follow up patients data such as blood pressure, ECG, SpO2, temperature[5]. Another study, PIC microcontroller based on over the Internet. The study of remote patient monitoring system for measuring SpO2 and pulse rate data was conducted [6]. Diabetes is a chronic disease and the patients who have diabetes need to check their glucose level on a regular basis. For this purpose, a system containing smart phones has been developed and the measured level of glucose of the patients is easily monitored by the authorized person. For the ease of the monitoring process, this study is quite useful for patients who have diabetes [7].

Our study has differences and advantages by comparison with previous study. These differences are;
- vital parameters such as blood pressure, pulse, temperature, and body temperature are measured with the same apparatus,
- possibility of reaching the parameters at any moment thanks to generated interface,
- android mobile interface which observation of changes in vital signs,
• The database created for storing the measured values (can observe measurement frequency and values).
• The systems send to message doctor and close family when the critical values determined for the patient.

Wired measurement systems used to measure vital parameters of the people. Then, vital parameters sent to a database. If Wi-Fi connects, real-time and registered measurement results are recorded to patient record system. A convenient interface that permits the display of smart devices has been developed.

In this way,
• In the process of diagnosis and treatment of a disease, parameters can be monitored remotely on a regular basis with high quality and patient data can be accessed whenever required.
• Patients can be share their data at the same time with the authorized personnel or people can keep a record of their parameters and can compare it with the former recorded data.
• With remote monitoring of patients, it is expected that the hospital venues will be reduced, and also it may reduce the waste of time used for go to the hospital.
• Workload of the hospitals will be reduced.

II. MODELLING OF SYSTEM

Ensuring database of vital data is shown in Figure 1.

Arduino with the connection of sensors in the system is able to obtain blood pressure, pulse, body temperature, temperature and humidity of ambient data. Moreover, RTC and Wi-Fi modules are connected, so it is possible to use LCD

Blood pressure and pulse rate were obtained using MPX5050 pressure sensor which generates a voltage value that is produced by the pressure within the cuff. Body temperature data was taken with 18B20 temperature sensor using Arduino and environment temperature and humidity data were taken with DHT11 sensor. The measured data via the Arduino Mega have sent respectively through Wi-Fi module. Arduino application is used to transfer data to the web service written in order to evaluate the measured data. Arduino MEGA with algorithm for data processing of system is given in Figure 2.

![Figure 1: Ensuring database of vital data](image1.png)

![Figure 2: Arduino MEGA with algorithm for data processing of system](image2.png)

Patient data received by the Arduino module sent to the created web service for recording. The Arduino Mega and Wi-Fi connection is given in Figure 3.

![Figure 3: The Arduino Mega and Wi-Fi connection](image3.png)
Blood pressure and pulse rate measurements were carried out using PIC18F2550. In this study, the oscillometric method was preferred. Finally, the PIC18F2550 and Arduino communication was conducted and systolic and diastolic pulse values in PIC were sent to the Arduino. Arduino distinguished the values here and printed them on the LCD screen.

Changes in vital data of patients and humidity and temperature data of ambient were transferred to android operating system-based mobile devices via Wi-Fi. This system design of android was carried out with MIT app inventor 2 programming.

System consists of five main screens. These are a login screen, an information screen which gives information about person, a user record screen, a user interface which has user list, and a user data screen which has real and past time data of users.

The patient is required to fill up the information that is considered as important by the doctor such as full name, gender, age, health history etc. User data screen and information screen are shown in Figure 4.

All parts of the system is shown in Figure 6.

<table>
<thead>
<tr>
<th>Part of system</th>
<th>Explanation of System Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Designed PIC18F2550 circuit</td>
</tr>
<tr>
<td>2</td>
<td>Nextion LCD screen</td>
</tr>
<tr>
<td>3</td>
<td>Arduino Mega which all data collected by the electronic brain</td>
</tr>
<tr>
<td>4</td>
<td>Motor and valve used to inflate and deflate the sleeve of blood pressure monitor</td>
</tr>
<tr>
<td>5</td>
<td>Printed circuit to gather vital information and environment measurements</td>
</tr>
</tbody>
</table>

After Arduino code is compiled and loaded to controller, patient's data are sent to the database via Wi-Fi. Figure 7 shows the circuit is used 18F2550 microcontroller and external devices for adjusting the physical condition of the sleeve.

Table I. The parts used in the system setup.

After obtaining the personal information of the patient, Wi-Fi connection is made possible to gather the data via the sensors connected to the Arduino. Database screen generated for patients is shown in Figure 5. As shown in Figure 5, data is displayed by typing the patient's ID at any time.

Next step, design is made for modules and it is combined in a single electronic card. RTC module and sensor communication is shown in Figure 8. As shown in Figure 8, the circuit consists of RTC module, 18B20 body temperature sensor, Wi-Fi module and DHT11.
Finally, you can see General view of the system show in Figure 9.

### III. CONCLUSIONS

Nowadays more developments in biomedical field is valuable in terms of investing in people health. So, this study will facilitate the monitoring of human health, providing information about the health of person and information can be accessed on demand. Remote monitoring of the patient with smart devices is practical thanks to ease of movement. It can be utilized to diagnose and long-term monitoring of certain diseases as a portable data logger. Moreover, at next studies, system can be minimize and system weight’s can be reduced. Besides vital data, for medical purposes sensor data such as ECG, EKG, pulse oximetry, blood pressure, ventilation can be added to the system. The data obtained can be interpreted as artificial intelligence techniques and inferences can be made. If the spread of the system with an application that can be downloaded to smart devices, people can be informed more clearly.

### REFERENCES


Design and Construction of a Novel Micro-Extrusion System for Bio-printing Applications

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Abstract— Three-dimensional (3d) bio-printing is one of the major research fields of future, as yet at the beginning stage but producing promising solutions in medicine. As technology evolves, novel systems emerge for positioning even a single cell to the desired place to create functional tissues. The precision of these systems determine the functionality of outputs. In general, bio-printers use Ink-jet, Micro-extrusion and Laser Assisted printing methods to construct a solid tissue or a part of an organ. Ink-jet method, also known as drop-on-demand bio-printing approach, is based on spraying cells by means of thermal or piezo electric pulses from numerous nozzles and is commonly used when forming tissues like skin and cartilage. Micro-extrusion method is used when complex biological structures like blood vessels or solid organs are bio-printed. Laser Assisted method is more preferred for biomaterial or implant production. Components of these systems have direct effects on the output since they determine where and how much biological material will be deposited in every layer. The aim of this study is to design and construct a novel micro-extrusion module for bio-printing applications. The designed module consists of three-dimensional (3d) printed body parts from Polylactic acid (PLA), Nema type stepper motors, ball screws (SFU1204), ball screw nuts (M12), flexible couplings (5 x 8 x 25 mm), steel rods (M8), SCE EE series bearings (SCE 8 UU), UFL series bearings (UFL 08), LMEF series bearings (LMEF 8 UU), SK series rod holders (SK 08) and has an ability to control three commercially available syringes with blunt ended needles. For precise micro-extrusion, galvanized steel rods support ball screw driven linear motions. Ergonomically, syringes can be easily mount and locked and this system also has laser holders that can be used for targeted photo polymerization.

Keywords— Bio-printing, Micro-extrusion module, Three syringes, Photo polymerization.

I. INTRODUCTION

Three-dimensional (3d) bio-printing is based on biomaterial localization in limited conditions to construct functional tissues or a part of an organ generally using ink-jet, micro-extrusion and laser assisted bio-printing methods [1]. The applicability of these systems is similar to two-dimensional (2d) printers, however this technology uses biological materials instead of an ink [2]. The system of a bio-printer consists of electrical, mechanical and software components to carry out controlled biological material deposition [3]. Mechanical components such as main frame, bearings, rods and other parts have direct effect on the movement ability and determine the physical limits of the machine. Electrical parts are used to control these mechanics and can be mentioned as a mainboard, typical driven stepper or servo motors, mechanical or optic limit switches, thermistor or thermocouples, heaters and other human computer interfaces like LCD (Liquid Crystal Display) or keypad. The software can be separated as Firmware that is also embedded in MCU (Micro Controller Unit) and host software can be controlled via PC (Personal Computer). Firmware is a library that determines the whole system by means of loops, variables and values that have direct effects on efficiency. Although there are several differences between a milling, drilling or grinding machine and a 3d bio-printer, the implementation of these systems and fundamental components have similarities. In fact, printing technology, print head and printed material are developed or chosen independently of one another when designing stage of these systems according to the purposes [4]. Printouts are dependent on the precision of the whole microfabrication system and biomechanical characteristics of the bio-inks [5].

It should be noticed that additive manufacturing technology is accepted as a different way of producing things from the traditional methods, nevertheless they both have similar components [6].

The design of the system of interest is shaped by means of purposes that determine the limits of imagination.

A. Basics of Bio-printing Technologies

As technology evolves, novel systems emerge for positioning even a single cell to create functional tissues [7]. The precision of these systems determine the functionality of outputs. In general, bio-printers use Ink-jet, Micro-extrusion and Laser Assisted printing methods to construct a solid tissue or a part of an organ [8]. Ink-jet method uses generated droplets down to 20 microns in diameter via the magnitude of applied thermal or piezo-electrical forces [9]. As a result of spraying living cells from numerous nozzles, non-complex
biological structures like skin and cartilage can easily be formed with ink-jet based printing. Figure 1 illustrates one of the numerous nozzles from a print head that uses ink-jet bio-printing approach.

Micro-extrusion method has an ability to form complex biological structures like blood vessels, heart valves and solid organs [10]. Extrusion of biomaterials can be performed by means of a piston, an extrusion screw or compressed air. All these print heads have similar continuous material deposition with different types of mechanisms. Syringes are used as hydrogel tanks and chosen according to the deposition technique. Blunt end needles are preferred as nozzles and diameters of needles depend on the cell sizes used in bio-printing process. Print heads and the biomaterials used should be chosen carefully in order to prevent shear stress of hydrogels that may occur during material deposition [11]. Shear stress can cause cell death that directly affects the functionality of output tissue constructs. Figure 2 illustrates the three deposition techniques used in micro-extrusion bio-printing approach.

Laser assisted method is more preferred for implant production [12]. The wavelength of laser beam is critical for cell viability when biological materials are exposed and this has a direct effect on the output. In order to prevent cell death and improve output tissue’s functionality, an energy absorbance layer is used. This method is based on selective biomaterial detachment from donor side to the substrate via laser pulses, and is the most expensive technique when compared with all techniques. Thus, laser assisted method is used for more precise applications. Figure 3 illustrates the laser assisted bio-printing approach.
II. MATERIAL AND METHOD

Prototype manufacturing has stages extending from blueprints to the end usage. Initially, target system is drawn as 2d (two-dimensional) sketches. The main frame or other parts are shaped according to the desired functionality. The model of design is taken to its final form by means of a 3d Computer Aided Design (CAD) software. This helps to see the whole assembly and bill of materials (BOM).

Figure 4 illustrates the assembled parts of prototype on CAD software [13].

Figure 5 illustrates the designed syringe holders.

Table 1 illustrates the BOM of the whole module.

<table>
<thead>
<tr>
<th>Group</th>
<th>Piece(s)</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical</td>
<td>3</td>
<td>Nema stepper motor</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Ceramic heater</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Thermocouple or thermistor</td>
</tr>
<tr>
<td>Mechanical</td>
<td>4</td>
<td>Steel rod</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Ball screw</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Ball screw nut</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Flexible coupling</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>SCE UU series bearing</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>SHF series bearing</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>LMEF series bearing</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>SK series rod holder</td>
</tr>
<tr>
<td>3d printed</td>
<td>1</td>
<td>Main frame</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Syringe holder</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>Syringe</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Steel blunt-ended needle</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Laser</td>
</tr>
</tbody>
</table>
The main frame and syringe holders were manufactured from Polylactic acid (PLA) polymer with 60% infill rate and 200 μm layer height by using a 3D printer. Figure 6 illustrates the 3D printed main frame.

Support parts are removed after the printing is completed. Figure 7 illustrates the assembly of the module.

III. CONCLUSIONS

The designed micro-extrusion module successively passed the bio-printing tests. Advantages of this system can be summarized as follows:

- Number of printing heads can be duplicated according to the needs and complexity of the target tissue constructs,
- Design can be scalable for different types of mechanical and electrical components,
- Steel rods support ball screw driven linear motions for precise micro-extrusion,
- Ergonomically, syringes can be easily mounted and locked,
- System has laser holders that can be used for targeted photo polymerization,
- Heaters and temperature sensors can be easily mounted,
- This module has compatibility for any type of bio-printer.

First bio-printing tests were carried out on a bio-printer after integration of the designed module. In order to test durability and accuracy of this system, hybrid hydrogels of wide concentration range were prepared as bio-inks from natural polymers. Figure 8 illustrates the bio-printing process by means of the assembled micro-extrusion module.

Fig. 6 Main frame

Fig. 7 Assembly process of the module: front view a) and back view b).

Fig. 8 The bio-printing process by means of the assembled micro-extrusion module (24-gauge needle was used): a) without optimized bio-printing parameters and bio-ink b) with optimized bio-printing parameters and bio-ink. (hand-held microscope image)
ACKNOWLEDGMENT

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REFERENCES


A Genuine GLCM-based Feature Extraction for Breast Tissue Classification on Mammograms

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Abstract—A breast tissue type detection system is designed, and verified on a publicly available mammogram dataset constructed by the Mammographic Image Analysis Society (MIAS) in this paper. This database consists of three fundamental breast tissue types that are fatty, fatty-glandular, and dense-glandular. At the pre-processing stage of the designed detection system, median filtering and morphological operations are applied for noise reduction and artifact suppression, respectively; then a pectoral muscle removal operation follows by using a region growing algorithm. Then, 88-dimensional texture features are computed from the GLCMs (Gray-Level Co-Occurrence Matrices) of mammogram images. Besides, a formerly introduced 108-dimensional feature ensemble is also computed and cascaded with the 88-dimensional texture features. Finally, a classification process is realized using Fisher’s Linear Discriminant Analysis (FLDA) classifier in four different classification cases: one-stage classification, first fatty – then others, first fatty-glandular – then others, and first dense-glandular – then others. A maximum of 72.93% classification accuracy is achieved using only texture features whereas it is increased to 82.48% when cascade features are utilized. This consequence clearly exposes that the cascade features are more representative than texture features. The maximum classification accuracy is attained when “first fatty-glandular – then others” classification case is implemented, that is consistent with the fact that fatty-glandular tissue type is easily confused with fatty and dense-glandular tissue types.

Keywords-breast tissue; digital mammography; feature extraction; computer-aided detection

I. INTRODUCTION

Breast cancer is the second major cause of female deaths all over the world [1]. Although early diagnosis helps mortality to reduce, suspicious mass detection from mammograms becomes harder as breast tissue type becomes denser. Hence, it will be efficient to use a Computer-Aided Detection (CAD) system which can first define the breast tissue type of a mammogram, then detect and diagnose the type of breast cancer. Basically three major problems occur during breast tissue type classification: digitization noise, artifacts like labels of the mammograms, and pectoral muscle regions in the images. Since digitization noise appears as a high-frequency component in an image, smoothing filter implementation such as mean and median filtering is needed for noise reduction [2]. Besides, histogram processing operations [2], curvelet transform [3], wavelet transform [4], and top-hat transform [5] are commonly used noise reduction methods in the literature.

Another problem is the formation of unwanted artifacts like right/left breast or Craniocaudal (CC)/Mediolateral-Oblique (MLO) shooting labels in the background. This problem is generally handled by the separation of the breast parenchyma from the background applying morphological operations [2], thresholding [6], using gradients [7], and active contours [8].

Almost the most important intensity-based problem for breast tissue classification is the existence of pectoral muscles on the mammogram images. Pectoral muscles show up like triangle geometry at any of the top corners on the mammogram having brighter intensities than breast parenchyma. The studies on pectoral muscle removal in the literature generally focus on intensity-based and wavelet-based approaches. These approaches are examined under three main topics which are line detection techniques, statistical techniques, and other approaches.

Recent studies on breast tissue type classification mainly performed by Scale Invariant Feature Transforms (SIFT) descriptors [20-23] and texton histograms [20, 22, 24]. In addition to them, local features obtained from Local Binary Pattern (LBP) [20, 24], Haralick texture descriptors [25, 26], Soh features [26], visual word histograms [27], and histogram moments [28-29] are other well-known techniques used for breast tissue type classification.

In this paper, the design of a CAD system for breast tissue type classification of mammogram images is aimed. In accordance with this purpose, noise reduction and artifact suppression are initially realized on mammogram images in the database using median filter and morphological operations, respectively. Then, a pectoral muscle removal process is executed using region growing algorithm. These pre-processing operations are elaborately explained in Section 2. A feature extraction procedure explained in Section 3 is performed on the pre-processed mammogram images. The experimental study employed in this paper and all conclusions are given in Sections 4 and 5, respectively.
II. PRE-PROCESSING

Digitization noise, low/high-level artifacts in the background and presence of pectoral muscles, as shown on the sample mammogram image in Fig. 1, obstruct intensity-based breast tissue type classification of mammogram images. Hence, a pre-processing stage is essential in order to reduce noise, suppress artifacts, and remove pectoral muscles on original mammogram images.

A. Noise Reduction

Smoothing filters are used for noise reduction although they cause loss in gross details in an image. Hence, the use of filters that can remove noise as well as preserving edge details is essential. In this paper, noise reduction is carried out via median filtering. The median filter is a commonly preferred non-linear filter for noise reduction [30]. This filter is capable of preserving edge information while removing differences between pixels in the pre-defined neighborhood.

B. Artifact Suppression

Morphological operations are applied for both low and high-level artifact suppressions after noise reduction step. In this respect, the mammography images are converted into their corresponding binary level images. Then, the largest area is assumed to be breast parenchyma on each binary level image since its area should be greater than the area occupied by an artifact.

C. Pectoral Muscle Removal

Region growing algorithm is performed for pectoral muscle removal process in this study. Region growing algorithm, a region-based segmentation method, splits all pixels in an image directly into sub-regions by taking the pre-defined similarity conditions for the growing process into consideration [31]. This algorithm is based on an enlargement of regions by aggregating the pixels with similar properties. For this purpose, initially, a similarity condition and a seed point or a set of seed points are defined. Specified seed/seed set is considered as the initial sub-region and the pixels around 4 or 8-neighbors of each pixel are considered in terms of similarity condition.

III. FEATURE EXTRACTION

A. Gray-Level Co-Occurrence Matrix (GLCM)

GLCM is one of the commonly used methods for texture analysis and it compares the gray-level differences of any two neighbor pixels in a specified displacement and direction on an image [32]. In other words, GLCM of an image comprises of a function of the angular relationship and a distance between pixels in the neighborhood [33]. The GLCM of an image I, of size \( N \times N \), is formulated in (1):

\[
p(i, j) = \sum_{x=0}^{N} \sum_{y=0}^{N} [1, I(x, y) = i \text{ and } I(x + \Delta_x, y + \Delta_y) = j]
\]

where \( p(i, j) \) in (1) refers to the joint probability of co-occurrence of intensities \( i \) and \( j \) at a given offset \((\Delta_x, \Delta_y)\) where \( x \) and \( y \) are the spatial positions in the image. The offset \((\Delta_x, \Delta_y)\) specifies the distance \( d \) and the angle \( \Theta \) between the pixels \((x, y)\) and its neighborhood.

B. GLCM Texture Features

Texture features, introduced by Haralick et al. [34], Soh et al. [35], and Clausi [36], are extracted from the GLCMs of mammograms in this paper. These features and their mathematical representations are given in Table I.

<table>
<thead>
<tr>
<th>Feature No.</th>
<th>Feature Name</th>
<th>Mathematical Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GLCM Texture Features</td>
<td></td>
</tr>
</tbody>
</table>
| \( p(i, j) \) : GLCM | \[
p(i, j) = \sum_{x=0}^{N} \sum_{y=0}^{N} [1, I(x, y) = i \text{ and } I(x + \Delta_x, y + \Delta_y) = j]
\] |
| \( p_x(i) = \sum_{j=1}^{N_x} p(i, j) \quad p_y(i) = \sum_{i=1}^{N_y} p(i, j) \) | \[
p_x(i) = \sum_{j=1}^{N_x} p(i, j) \quad p_y(i) = \sum_{i=1}^{N_y} p(i, j)
\] |
| \( \mu_x = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} i \cdot p(i, j) \quad \mu_y = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} j \cdot p(i, j) \) | \[
\mu_x = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} i \cdot p(i, j) \quad \mu_y = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} j \cdot p(i, j)
\] |
| \( \sigma_x = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (i - \mu_x)^2 \cdot p(i, j) \quad \sigma_y = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (j - \mu_y)^2 \cdot p(i, j) \) | \[
\sigma_x = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (i - \mu_x)^2 \cdot p(i, j) \quad \sigma_y = \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (j - \mu_y)^2 \cdot p(i, j)
\] |
| \( f_1 \) | Autocorrelation [35] | \[
\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (i - \mu_x) \cdot (j - \mu_y) \cdot p(i, j)
\] |
| \( f_2 \) | Contrast [34, 35] | \[
\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} \left( i^2 + j^2 - 2 \cdot i \cdot j \cdot p(i, j) \right)
\] |
| \( f_3 \) | Correlation (MATLAB) | \[
\frac{\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (i - \mu_x) \cdot (j - \mu_y) \cdot p(i, j)}{\sigma_x \cdot \sigma_y}
\] |
| \( f_4 \) | Correlation [34, 35] | \[
\frac{\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} (i \cdot j - \mu_x \cdot \mu_y) \cdot p(i, j)}{\sigma_x \cdot \sigma_y}
\] |
| \( f_5 \) | Cluster Prominence [35] | \[
\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} [i - j \cdot \mu_x - \mu_y] \cdot p(i, j)
\] |
| \( f_6 \) | Cluster Shade [35] | \[
\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} [i - j \cdot \mu_x - \mu_y] \cdot p(i, j)
\] |
Feature No | Feature Name | Mathematical Representation
--- | --- | ---
$f_1$ | Dissimilarity [35] | $\sum \sum (1 - A_{ij} \cdot p(i, j))$
$f_2$ | Energy [34, 35] | $\sum \sum (p(i, j))^2$
$f_3$ | Entropy [35] | $\sum \sum \frac{1}{1+j} \cdot p(i, j)$
$f_4$ | Homogeneity (MATLAB) | $\sum \sum \frac{1}{1+(i-j)^2} \cdot p(i, j)$
$f_5$ | Homogeneity [35] | $\sum \sum \frac{1}{1+(i-j)^2} \cdot p(i, j)$
$f_6$ | Maximum Probability [35] | $\max p(i, j)$
$f_7$ | Sum of Squares: Variance [34] | $\sum \sum (i - \mu)^2 \cdot p(i, j)$
$f_8$ | Sum Average [34] | $\sum \sum i \cdot p_{x+y}(i)$
$f_9$ | Sum Variance [34] | $\sum \sum (i - f(i))^2 \cdot p_{x+y}(i)$
$f_{10}$ | Sum Entropy [34] | $\sum \sum p_{x+y}(i) \cdot \log p_{x+y}(i)$
$f_{11}$ | Difference Variance [34] | $\sum \sum (i - j)^2 \cdot p_{x+y}(i)$
$f_{12}$ | Difference Entropy [34] | $\sum \sum (i - j) \cdot \log p_{x+y}(i)$
$f_{13}$ | Information Measure of Correlation1 [34] | $\max(I_{HX}, I_{HY})$
$f_{14}$ | Information Measure of Correlation2 [34] | $I_{HX} = \sum \sum \frac{p(i, j) \cdot \log p(i, j)}{p_x(i) \cdot p_y(j)}$
$f_{15}$ | Inverse Difference Normalized [36] | $\frac{\sum \sum p_{x+y}(i) \cdot \log p_{x+y}(i)}{\sum \sum p_{x+y}(i) \cdot \log p_{x+y}(i)}$
$f_{16}$ | Inverse Difference Moment Normalized [36] | $\frac{\sum \sum p_{x+y}(i) \cdot \log p_{x+y}(i)}{\sum \sum p_{x+y}(i) \cdot \log p_{x+y}(i)}$

Texture features, extracted in this paper, give information about the homogeneity, symmetry, complexity, and contrast in the GLCMs of the mammogram images.

IV. EXPERIMENTAL STUDY

In this paper, a CAD system that classifies mammogram images into the breast tissue types of fatty, fatty-glandular, and dense-glandular is proposed. Firstly, a pre-processing of mammogram images is performed where median filtering and morphological operations are applied for noise reduction and artifact suppression, respectively; then a pectoral muscle removal process follows by using region growing algorithm. Secondly, at the feature extraction stage, 88-dimensional texture features are computed from the GLCMs of mammogram images. Finally, classification is realized using Fisher’s Linear Discriminant Analysis (FLDA) in four different classification cases.

A. Database

A publicly available mammogram database constructed by the Mammographic Image Analysis Society (MIAS) is used in this paper [37]. This database consists of three health status classes (normal, benign, malignant) for each of three breast tissue type classes (fatty, fatty-glandular, and dense-glandular). It has 322 MLO mammogram images (106 fatty, 104 fatty-glandular, and 112 dense-glandular) with 330 diagnosis (207 normal, 69 benign, and 54 malignant). The images in the MIAS database are of size 1024x1024 at 200 μm/pixel resolution and they are in “.pgm” imaging format.

All mammogram images in the database are resized into a size of 256x256 for ease of operation. Sample images of each class in the MIAS database are shown in Fig.2. The rows and columns in the Fig.2 show three different samples of health status and breast tissue types.

![Sample mammogram images in the MIAS database.](image)

B. Feature Vector Construction

In this paper, the texture features, given in Table I, are computed from the GLCMs of the mammogram images.

The GLCMs of mammogram images are obtained in four different rotation directions which have an angle of $\theta = 0^\circ, 45^\circ, 90^\circ, 135^\circ$ using four different pixel distances $d = \{1, 2, 3, 4\}$. Hence, four co-occurrence matrices are evaluated for each rotation direction, and 22-dimensional textural feature vectors are computed from each of co-occurrence matrices. Then, the average of these four matrices is calculated so that a 22-dimensional feature vector is constructed for the corresponding direction. Ultimately, 88-dimensional feature vectors for each mammogram image are obtained by concatenating four different 22-dimensional feature vectors of each direction.
C. Classification

Breast tissue type classification is performed in one-stage and two-stage processes in this paper. In the one-stage classification process, mammogram images are directly categorized as having fatty, fatty-glandular, and dense-glandular tissue types. Besides, the two-stage classification process is carried out in three different ways: first fatty – then others, first fatty-glandular – then others, and first dense-glandular – then others.

In the first stage of the “first fatty – then others” classification process, the mammogram images are primarily classified as fatty and non-fatty mammograms. Then, in the second stage, the mammograms labeled as non-fatty are classified as fatty-glandular and dense-glandular. Similarly, in the “first fatty-glandular – then others” classification case, mammograms are firstly classified as fatty-glandular and non-fatty-glandular, and then non-fatty-glandular mammograms are classified as fatty and dense-glandular. Finally, in the “first dense-glandular – then others” classification case, mammograms are initially categorized as dense-glandular and non-dense-glandular, and then non-dense-glandular mammograms are classified as fatty and fatty-glandular.

D. Performance Evaluation

In this paper, a breast tissue type detection system is designed for four different classification cases using FLDA classifier. Average and fold-by-fold classification accuracies of FLDA classifier are given in Table II when only texture features are used.

The maximum average classification accuracy of 72.93% is achieved when “first fatty-glandular – then others” classification case is implemented.

In addition to the GLCM texture features, the 108-dimensional feature ensemble introduced in [38] is computed in order to increase the data representability of the existent GLCM features. This 108-dimensional feature ensemble is formed as the concatenation of some statistical and frequency-domain features to the LCP-based feature vectors [38]. Then, the 88-dimensional texture features and the 108-dimensional feature vectors are spliced. Consequently, 196-dimensional feature vectors are obtained for each mammogram image. Average and fold-by-fold classification accuracies are given in Table III when the spliced 196-dimensional features are used.

V. CONCLUSION

In this paper, a Computer Aided Detection (CAD) system for breast tissue type classification is designed, and it is verified on a popular mammogram database compiled by the Mammographic Image Analysis Society (MIAS). This database consists of the mammograms of three fundamental breast tissue types namely fatty, fatty-glandular, and dense-glandular. The 88-dimensional texture features computed from GLCMs of the mammogram images, are concatenated to the 108-dimensional feature ensemble. Ultimately, 196-dimensional feature vectors are obtained for each mammogram image and then they are classified using Fisher’s Linear Discriminant Analysis (FLDA) classifier in four different classification cases: one-stage classification, first fatty – then others, first fatty-glandular – then others, and first dense-glandular – then others.

A maximum of 72.93% classification accuracy is achieved using only texture features while it is increased to 82.48% when the final 196-dimensional feature vectors are employed. This consequence clearly implies that the final concatenated feature vectors are more descriptive than texture features. Besides this finding, the increase in the number of the dimension for the evaluated feature vectors reveals more representative vectors so that mammogram images are eventually characterized more effectively.
The maximum classification accuracy is reached when "first fatty-glandular – then others" classification case is performed. It is already known by radiologists that fatty-glandular tissues can easily be confused with fatty and dense-glandular tissue types. Hence, it would be wisely to detect glandular tissues can easily be confused with fatty and dense-glandular tissues. Therefore, it would be wisely to detect glandular tissues can easily be confused with fatty and dense-glandular tissues. This reality is quite coherent with the classification process that gives maximum classification accuracy.

REFERENCES


Abstract—In this study, a novel perfect absorber (PA) array based on four-headed arrow nanoparticles for biosensing applications in mid-infrared regime is presented. Proposed PA array has a dual-band spectral response, and the locations of resonances can be adjusted by varying the geometrical dimensions of the structure. Nearly unity absorbance is obtained from the PA array for both resonances. Different dielectric spacers (MgF\(_2\), SiO\(_2\), and Al\(_2\)O\(_3\)) are used to investigate the effects of dielectric spacer on the absorbance characteristics of proposed PA array. Absorbance characteristics of PA array are analyzed by using finite difference time domain (FDTD) method. High field enhancement is achieved by the interaction of the sharp corners of arrow nanoparticles. Linear correlation between the resonance frequencies and the refractive index of cladding mediums is determined. Due to the high refractive index sensitivity and near-field enhancement, the proposed dual-band PA array with adjustable spectral responses can be useful for biosensing applications in mid-infrared regime.

Keywords—Perfect absorber, Plasmonics, Nanoparticle, Mid-infrared regime, Biosensing applications

I. INTRODUCTION

A new research area of plasmonic structure is getting attention, known as plasmonic perfect absorbers (PAs) [1–6]. The concept of metamaterial PAs came from microwave regime, due to the advancement in the nanotechnology; it can be scaled down to the terahertz regime [7, 8]. The possibility of perfect absorption is revealed by appropriately engineering the electric and magnetic response of the incident field in gigahertz regime [7, 8]. The PAs are composed of periodically arranged resonant metallic nanoparticles and thin metal layer separated by a dielectric spacer [2, 5, 9]. There are many advantages of this kind of structures which include high absorptivity, small thickness, and low density [10]. With this type of device configuration, wide-angle, wide-band, and polarization-insensitive high absorption near unity can be achieved by matching the impedance of metamaterial absorbers to free space or with microcavity, hole arrays, and metallic surfaces [5, 9-11]. PAs operating in the infrared and visible regions have been used for biomedical sensing, surface-enhanced spectroscopy, and near-field scanning optical microscopy applications [1-15].

In this study, a four-headed arrow nanoparticle shaped PA array for biosensing applications in mid-infrared regime is presented. The optical properties of plasmonic PA array are investigated by using the finite difference time domain (FDTD) method [16]. In order to understand the physical origin of the resonant behavior and determine the field enhancement of the nanostructure, near field distributions at the resonant frequencies are obtained. Due to dual band spectral response and enhanced near field distribution, the proposed PA array can be useful for biosensing applications in mid-infrared regime.

II. NUMERICAL ANALYSIS

Schematic view of proposed PA is illustrated in the Fig. 1(a). It consists of a dielectric spacer layer between nanoparticle-based top layer and gold (Au) film on a dielectric substrate (Si). Dielectric substrate thickness is 500 nm, gold film thickness is 200 nm, dielectric spacer layer thickness is 125 nm and four-headed arrow shaped gold nanoparticle thickness is 50 nm. In Fig. 1(a), L and d indicate the length and weight of rectangular nanorods, respectively. \(h_1\) indicates the heights of left and right triangular nanoparticles and \(h_2\) indicates the heights of top and bottom triangular nanoparticles. \(w_1\) indicates the base-weights of left and right triangular nanoparticles and \(w_2\) indicates the base-weights of top and bottom triangular nanoparticles. Periodicities, \(P_x\) and \(P_y\), of the array are 2000 nm. During the simulations, the analyses are performed under y-polarization illumination source and geometrical dimensions are chosen as \(L = 1000\) nm, \(w_1 = 750\) nm, \(w_2 = 700\) nm, \(h_1 = 400\) nm, \(h_2 = 350\) nm, and \(d = 350\) nm. Periodic boundary conditions are chosen as x- and y-axes, and perfectly matched layers are used along the z-axis. The dielectric constants of the materials are taken from Ref. [17].

Different dielectric spacers (MgF\(_2\), SiO\(_2\), and Al\(_2\)O\(_3\)) are used to investigate the effects of dielectric spacer on the absorbance characteristics of proposed PA array. The absorbance (A) spectra of the structure for different dielectric spacer (MgF\(_2\), SiO\(_2\), and Al\(_2\)O\(_3\)) are given in Fig. 1(b). It can be seen from Fig. 1(b), all structures exhibit dual-resonant behaviors in mid-IR regime. Also for all dielectric spacers, the absorption rates are nearly unity.
Figure 2(a) shows the absorbance (A), reflectance (R) and transmittance (T) spectra of the PA with MgF₂ dielectric spacer. The absorbance spectra are calculated by A = 1 - R - T [13]. Proposed PA has dual resonances and both of them rate as %99.9 at the first (f₁ = 57 THz) and at the second (f₂ = 136 THz) resonances. Electric field distributions are given in Figs. 2(b) and 2(c) at first (f₁) and second (f₂) resonances, respectively. The near field enhancements are greater than 2000 times are concentrated on the sharp corners of the structure. Molecules in these corners may undergo a much stronger interaction with the electromagnetic field than those that lie well away from metallic particles. This means that the dielectric environment of the near surface region of the proposed PA array can strongly influence the resonant frequencies. This phenomenon is the basis of the mid-infrared biosensing capabilities of proposed PA array.

Figure 3(a) illustrates the A, R, and T spectra of the structure with SiO₂ dielectric spacer L = 1000 nm, w₁ = 750 nm, w₂ = 700 nm, h₁ = 400 nm, h₂ = 350 nm, and d = 350 nm. Proposed PA has dual resonances and both of them rate as %99.8 at the first resonance (f₁ = 58 THz) and %99.9 at the second resonance (f₂ = 132.5 THz). Electric field distributions are given in Figs. 3(b) and 3(c) at first (f₁) and second (f₂) resonances, respectively. The near field enhancements are greater than 1500 times are concentrated on the sharp corners of the structure.
Figure 5 demonstrates the changes in the spectral response for different d, L, h₁, h₂, w₁, w₂, and P parameter values. When the d (weight of rectangular nanorods) increases, both of the resonance frequencies increase (Fig. 5a). Absorption spectra for L (length of rectangular nanorods) variation is given in Fig. 5b, which shows that both resonance frequencies of the structure decrease with the increasing length of rectangular nanorods, both of the resonance frequencies decrease. As the h₁ (heights of left and right triangular nanoparticles) increases, only second resonance frequency decreases slightly (Fig. 5c). When the h₂ (heights of top and bottom triangular nanoparticles) increases, only first resonance frequency decreases (Fig. 5d). When the w₁ (base-weights of left triangular nanoparticles) increases, only second resonance frequency decreases (Fig. 5e) however only first resonance frequency decreases (Fig. 5f) with increasing w₂ (base-weights of the top and bottom triangular nanoparticles). The dependence of absorption spectra on the periodicity (P) is shown in Fig. 5g, which shows that only second resonance frequency is affected by the periodicity (P) variation. The optical characteristics of the proposed PA arrays are dependent on geometrical parameters (Fig. 5). The resonance frequencies of the proposed PA arrays can be tuned by changing the geometrical dimensions of PA arrays.

In order to control the refractive index sensitivity of proposed PA array, the top of the structure is covered with cladding layers with different refractive indices (Fig. 6a). The cladding layer thicknesses are 100 nm. Linear correlation between the resonance frequencies and the refractive index of cladding mediums are determined. As the refractive index of the cladding medium increases, both of the resonance frequencies decreases (Fig. 6b).

![Fig. 5 Spectral response of proposed PAs (a) d variation and (b) L variation (c) h₁ variation (d) h₂ variation (e) w₁ variation (f) w₂ variation (g) P variation](image)

![Fig. 6 (a) Schematic view of the proposed PA with cladding medium (b) Linear dependence between resonance frequencies and refractive indices](image)
III. CONCLUSIONS

In conclusion, a novel plasmonic PA array based on four-headed arrow nanoparticles for biosensing applications in mid-infrared regime is presented. The spectral response and near field distributions of the proposed PA array are obtained by using the FDTD method. The effects of the dielectric spacer on the spectral responses of the proposed PA array are determined. The highest absorption rates and near field enhancements are obtained PA array for MgF$_2$ dielectric spacer. Due to the dual-band spectral response and enhanced near-field distributions, the proposed dual-band four-headed arrow based PA array with adjustable spectral responses can be used for mid-infrared biosensing applications.

ACKNOWLEDGMENT

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REFERENCES


Biomedical Considerations in Fracture Fixation Using Orthopaedic Implants

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Abstract — Orthopaedics is a highly technical field that employs a broad range of techniques, from microvascular surgery to bone fixation implants, to metallic and polymeric composite implants for joint replacement, to sophisticated methods of fixation involving all regions of the skeleton. The use of implants and devices requires sophisticated technical information on the part of the surgeon for the best chance of successful operations. The technical characteristics of applying internal and external fixation implants are critical to achieving bone union in the appropriate position and to avoid implant failure. The major problems encountered in plate fixation of fractures are early plate failures, screw breakage, and screw pull-out. The primary function of the plate is to maintain alignment as an internal splint, and to create compression between the fracture ends such that bone can transfer some of the applied load itself. There are two parameters that effect the performance of plates. Material properties which are the fundamental behaviours of a substance independent of its geometry and structural properties which are the ability of an object to resist bending under torsion, axial load, or bending is a function of its shape and distribution of material around the cross section. The goal of fracture fixation is understanding the basic parameters so that the device used for fracture fixation provides support for repair until adequate healing can occur. The purpose of this study was the investigation of the bending performance of the new designed plate by Finite Element Analysis (FEA) and biomechanical tests. Analysis of Ti6Al4V alloy was carried to estimate the bending limit. The results from the ANSYS FEA simulations were validated with experiments based on ASTM F382 standards.

Keywords — Finite Element Analysis (FEA), Biomechanics, Four-Point Bending, Plate Fixation.

I. INTRODUCTION

Osteosynthesis plates are often used in orthopaedic trauma surgery to provide fixation of fractured bone which act as structural support for the bone during bone healing and as a stress sharing or shielding device, depending on the fracture type and the construct of the fixation [1]. Using for healing of femur bone fracture, a bone beam assembly is shown in Fig 1. Metal plates for internal fixation of fractures have been used for more than 100 years. Although initial shortcomings such as corrosion and insufficient strength have been overcome, more recent designs have not solved all problems. Further research is needed to develop a plate that accelerates fracture healing while not interfering with bone physiology [2].

In the surgery applications, patients with fractures are generally treated using bone plates made of stainless-steel, Cr–Co and Ti alloys. Although exhibiting reasonable fatigue strength, the stiffness of these metals (in between 110 and 220 GPa) is much higher than that of human cortical bone (around 20 GPa) [3]. As a result, the majority of the load is carried by the plate rather than by the underlying bone [4].

Although the application of a plate may seem simple, it is necessary to understand how the plate functions in order that optimal strength and stability of the internal fixation can be achieved. So, plates used for internal fixation are strongest in tension or compression and weakest in bending [5]. Bending behavior of a bone plate is one of the most critical mechanical properties from an application viewpoint, and is generally evaluated by maximum bending moment and bending stiffness calculated from the initial linear moment against the total bending angle (angulation) of the plate [6]. Static strength is measured using destructive 4-point bending tests. From the static test data, Bending Stiffness (BS), Yield Bending Moment (YBM) and Maximum Bending Moment (MBM) are calculated [7].

FEA of the bone–bone plate assembly was carried out to calculate callus deformation, contact stresses, in order to simulate the surgery process and post-surgery loading conditions [8,9]. It’s important to find out the stress concentrations and deformation zones of implants, so FEA using ANSYS is the best method for analysis of stresses and deformations of Ti6Al4V [10]. Saidpour was studied that FEA was performed to examine the mechanical performance of different six-hole fracture plate designs under bending loading [11].

The main objective of this study is to evaluate mechanical testing and FEA of a new designed and manufactured Ti6Al4V material internal fixation plate using CNC machining, in order
to investigate the state of stress and strain in the assembly, as well as to examine and compare the performance of the assembly under different load conditions.

II. MATERIALS AND METHODS

A. Design of New Locking Compression Plate (LCP)

Nowadays, conventional plating is increasingly replaced by using internal fixators. Internal fixators are “plates” (splints) with completely locked screw heads. These implants are not pressed onto the bone and do not need any contact between implant and bone [12]. According to Perren, the foreign body effect that reduces resistance to infection is less caused by the foreign material than by necrosis (induced by the implant) and the dead space effect. In conventional plate osteosynthesis, necrosis of the cortical bone compressed under the plate is produced systematically. In contrast, locking plate fixation does not result in bone necrosis [13]. The move from a conventional plate to the locking plate is not truly an evolving implant, but rather a change in concept [14].

In this study, a new LCP was designed and technically detailed. It was 161 mm long and 13.5 mm wide with eight holes. The thickness of the plate was 4 mm. The plate has spherically counter bored 27 mm diameter round holes. The distance between the centers of the two inner holes was 14 mm. The remaining holes were equally spaced by 18.5 mm. Engineering design of the plate can be seen in Fig. 2.

B. Material Properties

Mechanical properties of biomaterials play a key role in deformability of bone plates. In this study, the metallic bone plate test sample (GR23 (Ti6Al4VELI)) which is newly designed and manufactured is used. This titanium alloy is approximately twice as flexible as stainless steel and at least one-third stronger. It’s also more resistant to corrosion than stainless steel, which has a tendency to experience crevice corrosion at the contact point between screw heads and plates. Plate failure can take place through these corrosion pits [15]. In addition, titanium material generally used in locking plates, does not form a foreign body membrane and therefore does not create a dead space effect with the implant [14]. The mechanical properties for Ti6Al4V can be seen in Table 1.

C. Four Point Bending Test Procedure and Testing

Because a bone structure is asymmetrical, the stresses may not be equally distributed. Bending may be produced by four forces (four-point bending) [17].

This test describes methods for static four-point bend testing of intrinsic, structural properties of metallic bone plates for surgical fixation of the skeletal system. The purpose is to measure bending strength and bending stiffness intrinsic to the design and materials of metallic bone plates.

Four-point bending test conducted using two rolling supports spaced A-B and C-D (38 mm), B-C (40 mm) and loading supports A-D (116 mm) shown in Fig. 3. The load and support rollers are manufactured using hardened steel. Loading point is the rolling type, and the diameter of both the loading and support rollers are 5 mm and 10 mm.

The Metallic Bone Plate test samples shown in Fig. 4 were tested in accordance with the “ASTM F 382-99 Standard Specification and Test Methods for Metallic Bone Plates” [18] test procedure using 2.5 kN capacity tensile test machine at room atmospheric conditions.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Density (kg/m³)</th>
<th>Yield Strength (Mpa)</th>
<th>Ultimate Tensile Strength (Mpa)</th>
<th>Poisson Ratio (%)</th>
<th>Young Modulus (Gpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ti6Al4V</td>
<td>4500</td>
<td>793</td>
<td>862</td>
<td>0.24</td>
<td>114</td>
</tr>
</tbody>
</table>

Fig. 2. Engineering design of the plate

Fig. 3 Four-Point Bending Test and Loading Rolling Supports

Fig. 4. The Bone Plate Test Samples
During test, applied equal loads at each of the loading points (a single load centered over the load points) at a constant rate of displacement as presented in Fig. 5. Measure the relative deflections between the support and loading points. C and D points are fixed points. These boundary conditions are similar to four point bending standards.

**III. RESULTS**

**A. Experimental Test Results**

Six test sample of new LCP was manufactured by CNC machining method was tested according to four point bending test standards. Force peak, force yield, deflection yield, deflection peak results were obtained for each test sample. Minimum, maximum and mean values of test results were demonstrated force at peak 1975.354N, 2252.391N, 2085.923N; force at yield 525.244N, 1530.818N, 1015.724N; deflection yield 0.212 mm, 5.588 mm, 2.904 mm; and deflection peak 15.759 mm, 18.713 mm, 17.236 mm, respectively.

It is clear from chart that at the mean force point (force at peak (N) = 2085.923) deflection can be seen as 17.236 mm as an average. Same is valid at yield point. Experimental Test Results are presented in Table II and in Fig. 8.
### Experimental Test Results

#### Table I

<table>
<thead>
<tr>
<th>Test No</th>
<th>Dimensions Bxh (mm)</th>
<th>Bending Strength @ Peak (N/mm²)</th>
<th>Bending Strength @ Yield (N/mm²)</th>
<th>Bending Modulus (N/mm²)</th>
<th>Force @ Peak (N)</th>
<th>Force @ Yield (N)</th>
<th>Deflection @ Yield (mm)</th>
<th>Deflection @ Peak (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10x8</td>
<td>64.097</td>
<td>42.656</td>
<td>586.009</td>
<td>2136.575</td>
<td>1421.866</td>
<td>4.836</td>
<td>18.713</td>
</tr>
<tr>
<td>2</td>
<td>10x8</td>
<td>67.572</td>
<td>15.757</td>
<td>584.713</td>
<td>2252.391</td>
<td>525.244</td>
<td>1.307</td>
<td>17.061</td>
</tr>
<tr>
<td>3</td>
<td>10x8</td>
<td>61.320</td>
<td>32.783</td>
<td>549.101</td>
<td>2044.000</td>
<td>1092.755</td>
<td>3.851</td>
<td>18.092</td>
</tr>
<tr>
<td>4</td>
<td>10x8</td>
<td>62.829</td>
<td>21.294</td>
<td>542.935</td>
<td>2094.308</td>
<td>709.805</td>
<td>0.212</td>
<td>15.759</td>
</tr>
<tr>
<td>5</td>
<td>10x8</td>
<td>60.387</td>
<td>45.925</td>
<td>550.813</td>
<td>2012.913</td>
<td>1530.818</td>
<td>5.588</td>
<td>17.524</td>
</tr>
<tr>
<td>Min</td>
<td>59.261</td>
<td>15.757</td>
<td>537.679</td>
<td>1975.354</td>
<td>525.244</td>
<td>525.244</td>
<td>0.212</td>
<td>15.759</td>
</tr>
<tr>
<td>Mean</td>
<td>62.578</td>
<td>30.472</td>
<td>558.542</td>
<td>2085.923</td>
<td>1015.724</td>
<td>1015.724</td>
<td>2.904</td>
<td>17.236</td>
</tr>
<tr>
<td>Max</td>
<td>67.572</td>
<td>45.925</td>
<td>586.009</td>
<td>2252.391</td>
<td>1530.818</td>
<td>1530.818</td>
<td>5.588</td>
<td>18.713</td>
</tr>
</tbody>
</table>

Fig. 8 Force-deflection characteristics of bending tests

### IV. CONCLUSIONS

Selection of plate geometry and material for surgical implants plays a vital role in bone fracture healing process. In this paper, newly designed and manufactured bone plate was modelled and analysed. Through these bending test and FEA, we have found out the bending performance and safe bending limits of the new designed plate. As a result, this plate design can be used successfully in the treatment of bone fractures.

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The Assessment of Time-Domain Features for Detecting Symptoms of Diabetic Retinopathy

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Abstract—Diabetes affects the capillary vessels in retina and causes vision loss. This disorder of retina due to diabetes is named as Diabetic Retinopathy (DR). Diagnosing the stages of DR is performed on a publicly available database (DiaraetDB1) via detecting the symptoms of this disease. Time-domain features are extracted and selected to classify a fundus image. Fisher’s Linear Discriminant Analysis (FLDA), Linear Bayes Normal Classifier (LDC), Decision Tree (DT) and k-Nearest Neighbor (k-NN) are used as the classification methods in the experimental benchmarking. The recognition accuracies are obtained using all features (68 features) and selected features separately. k-NN is observed as the best classification method for without feature selection case and it gives averagely 92.22% accuracy. For feature selection case, LDC gives the best average accuracy as 92.45% with maximum 7 carefully chosen features.

Keywords—sequential feature selection, diabetic retinopathy, microaneurysms, hemorrhages, exudates.

I. INTRODUCTION

Insufficient generation or low level of insulin causes the diabetes. This disease affects many parts of body, more particularly affects blood vessels of a retina. Diabetic Retinopathy (DR) is resulted from the damage of tiny blood vessels inside diabetic patient’s retina [1]. DR is a major cause of vision loss and blindness [2]. It has four stages that are mild non-proliferative, moderate non-proliferative, severe non-proliferative and proliferative. Besides, an early diagnosis can prevent a permanent visual disability.

Diagnosing DR is realized via detecting the symptoms of retinopathy from fundus (retinal) images that show the posterior part of eye. The symptoms of this disease are called as microaneurysms (MA), hemorrhages (HR), soft exudates (SE) and hard exudates (HE). Microaneurysm is the quite first symptom of DR. Due to a loss of pericyte, capillary vessels protrude and red small dots occur on the top layer of retina [3]. Microaneurysm also refers as red small dots. The second symptom is hemorrhages. The vessels are bleed due to lack of feeding. Their appearances are similar to microaneurysm, but they are shown at the inner layer and outer plexiform [4]. Another symptom is soft exudates. It occurs when the layer of nerve fiber is clogged because of small arteries choked. Soft exudates are also known as cotton-wool spots [5]. Soft exudates are mostly confined with micro-aneurysm and vessels that are hyper-permeable. The last symptom is hard exudates. They are accumulation of yellow fat and protein that are seeping from capillary vessels and microaneurysms [6]. These symptoms of DR are shown in Fig. 1 [7].

The early stage of this disease is mild non-proliferative DR. In this stage, microaneurysms occur at the retinal vessels. The next stage is moderate non-proliferative and micro-aneurysms are increased, hemorrhages and hard exudates are started during this stage. The third stage is severe non-proliferative DR. The lack of oxygen became apparent in retina and then hemorrhages and hard exudates are increased. In this stage, the scar tissue that is leading the visual loss is occurred. The last stage is proliferative DR and the new unhealthy vessels are started to generate due to the increase in lack of oxygen and lack of feeding. These new vessels are very delicate and started to bleed and then they may cause to a visual loss at any moment.

In literature, diagnosing the stages of DR is starting with detecting MA. In [8], a three-stage system is proposed to detect MA via using filters. First of all, the candidate regions of MA are determined from fundus images and then 15 features are extracted from these regions to classify MA. Those features are area, eccentricity, perimeter, compactness, mean, standard deviation, homogeneity, etc. A feature selection is not performed and hybrid classifier that combines Gaussian Mixture Model (GMM) and Support Vector Machine (SVM) is used. Another method for classifying DR is the detection of HR. In this methodology, HR is detected and then it is classified into three classes which are normal, moderate, severe non-proliferative DR [9]. Random Forests Tree is used for classification and eventually the proposed system has 90% accuracy while moderate and severe non-proliferative cases were 87.5% accurate. In [10], MA and HR are both detected for non-proliferative stages of DR. A geometric-based criteria, which are size, shape, roughness, edge sharpness, color, depth, etc., are used to classify HR and MA. In this study, the stage of DR is determined according to the number and location of them. Ultimately, the suggested system achieves sensitivity and specificity values of 89.47% and 95.65% for the classification of DR versus normal. Neural Network (NN) is used to classify moderate, severe non-proliferative, proliferative DR and normal stages using features such that red, green, blue layer perimeter, and area [11]. The proposed system gives more than 80% accuracy.
addition to these, detecting exudates also gives information about non-proliferative DR. In [12], hard exudates are detected and then mean, standard deviation, compactness, size, edge strength, etc. features are extracted from RGB fundus images. Multi-layer perceptron is applied and the given approach yields a 100% mean sensitivity, 84.0% mean specificity and 92.0% mean accuracy. Hard and soft exudates are identified and features are extracted using Gray Level Co-occurrence Matrix [13]. Entropy, contrast, energy and homogeneity are used as features and SVM is applied to classify fundus images into moderate and severe non-proliferative DR.

In this paper, the aim is to detect the symptoms of diabetic retinopathy. These symptoms are MA, HR, HE and SE. DIARETDB1 database, which is publicly available, includes 89 different retina images (fundus) including all symptoms. A new database is generated with five different classes for each symptom and normal (healthy) retinas. 17 time-domain features are extracted through four different window sizes constituted from each retina image. The features which have more discrimination power are selected via Sequential Forward Feature Selection (SFS) method. Fisher’s Linear Discriminant Analysis (FLDA) [14], Linear Bayes Normal Classifier (LDC) [15], Decision Tree (DT), and k-Nearest Neighbor (k-NN) are utilized as the classification algorithms to benchmark [16, 17].

The rest of the paper is organized as follows: Section II presents the extraction of features from fundus images. Section III explains the used classification algorithms briefly. Section IV presents the experimental work. Finally, conclusions and future work are given in Section V.

II. FEATURE EXTRACTION

Time-domain features are extracted using gray values of pixels [18]. 17 features are extracted from each fundus image for one window size. 3x3, 5x5, 7x7 and 9x9 windows are formed, therefore 68 features ($f_1, f_2, ..., f_{68}$) are obtained for each fundus image. An example of utilized non-proliferative gray level images is shown in Fig. 2. For normal (healthy) retinas, the values of all pixels in the utilized image are zero. The whitish pixels are indicated the parts for symptoms of MA, HR, SE and HE.

![Fig. 2 Non-Proliferative Gray Level Fundus Image](image)

The extracted features are calculated from the pixel values in the corresponding window. For each window size ($2r+1 \times 2r+1$), the center pixel of the window is located at $(p_{r+1}, p_{r+1})$ and the other indices of the pixels are shown in Fig. 4 and the extracted features for each window size are given in Table 1 [18].

![Fig. 3 Normal (Healthy) Gray Level Fundus Image](image)

![Fig. 4 The indices of pixels for a 3x3 window (r=1).](image)

| $p_{r-2r-1}$ | $p_{r-2r}$ | $p_{r-2r+1}$ | $p_{r-2r+2}$ | $p_{r-2r+3}$ |
| $p_{r+2r-1}$ | $p_{r+2r}$ | $p_{r+2r+1}$ | $p_{r+2r+2}$ | $p_{r+2r+3}$ |
| $p_{r+3r-1}$ | $p_{r+3r}$ | $p_{r+3r+1}$ | $p_{r+3r+2}$ | $p_{r+3r+3}$ |

Fig. 1 Symptoms of Diabetic Retinopathy (a) Microaneurysm (b) Hemorrhages (c) Soft Exudates (d) Hard Exudates [7]
between this study matrix difference covariance and calculate to within this function. This algorithm linear combination of features that categorizes classes of event. This algorithm in pattern recognition field.

\[ f \]  

Feature Index | Feature Name | Mathematical Representation  
--- | --- | ---  
1 | Gray Level |  
2 | Edge Magnitude |  
3 | Edge Direction |  
4 | Maximum |  
5 | Minimum |  
6 | Average |  
7 | Variance |  
8 | Standard Deviation |  
9 | Area Descriptor |  
10 | Moments |  
11 | Busyness |  
12 | Entropy |  
13 | Skewness |  
14 | Kurtosis |  
15 | Average Boundary |  
16 | Difference |  
17 | Contrast |  

III. CLASSIFIERS

Fisher’s Linear Discriminant Analysis is a well-known algorithm in pattern recognition field and it is used to find linear combination of features that categorizes classes of events. This algorithm is mostly used for two purposes that are linear classifier and dimensionality reduction. It projects data to find linear combinations with large ratios of between-class to within-class scatter. This ratio is referred as covariance matrix. According to Fisher’s criteria, a covariance matrix is calculated by multiplying the inverse of the within-class covariance and between-class covariance. The inter-class difference is maximized by means of this new covariance matrix.

Linear Bayes Normal Classifier is another algorithm applied in this study. In this method, a linear classifier is computed between classes that have normal densities with equal covariance matrices. The joint covariance matrix is weighted using class covariance matrices. A regularization is applied to eliminate small variance directions and then a new covariance matrix is computed via the leading principal components and smallest eigenvalues [19].

Decision Tree has decision nodes, branches, and leaf nodes that are referred as features, conditions, and classes, respectively. Information gain or purity are used to create nodes. Conditions (branches) are utilized to determine the following node. Algorithm proceeds with the related branch considering the correctness of the condition, however if the condition is false, it jumps into the other branch. Finally, a leaf node is reached and then the class information is obtained.

K-Nearest Neighbor has a lazy learning and it is a distance based classifier. Classification procedure is carried out according to the similarities of events. An event is assigned to a class that is the most common amongst its k-neighbor classes.

IV. EXPERIMENTAL STUDY

In this paper, the detection of the symptoms for DR disease from fundus images is proposed. First of all, 68 features are extracted from generated database that has 185 images with 5 classes. Secondly, classification is performed with all features. FLDA, LDC, DT and k-NN are used and the recognition accuracies are obtained. Thirdly, a feature selection method (SFS) is performed on all features and ultimately, the fundus images are again classified via same classifiers.

A. Database

A publicly available fundus image database that is DIARETDB1 is used [7]. This database includes 5 classes which are normal, mild, moderate, severe non-proliferative and proliferative DR. It has 89 fundus images (5 normal, 84 have non-proliferative and proliferative DR). These images have a size of 1500x1152. Each image is masked and preprocessed by some image processing operations and then they are saved in “.png” format. Besides, the ground-truths of them are provided. A new database is generated from ground-truths of those images. This new database has 185 images with 5 classes which are the same as abovementioned classes. The classes and the number of images are given in Table 2.

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Total Number of Fundus Images</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>23</td>
</tr>
<tr>
<td>Micro-Aneurysm</td>
<td>41</td>
</tr>
<tr>
<td>Hemorrhages</td>
<td>46</td>
</tr>
<tr>
<td>Hard Exudates</td>
<td>44</td>
</tr>
<tr>
<td>Soft Exudates</td>
<td>31</td>
</tr>
</tbody>
</table>
B. Feature Vector Construction

All fundus images in the database are separated into patches for the ease of extracting features. One image has divided into four patches and each of them has equal size of 375x288. The time-domain features, given in Table I, are computed from each patch. The average (mean) values of features are calculated from four patches for each fundus image and they are treated as feature vector for corresponding fundus image.

C. Classification

The generated database is divided into a training and a test sets which have 80% and 20% of the number of images in the database, respectively. The five-fold cross-validation is conducted while classification is performed by four different classifiers using MATLAB PRtools toolbox [19]. Then, the Sequential Feature Selection algorithm is applied to the training dataset. During this stage, the “sequentialfs.m” function in MATLAB is carried out and the criteria for feature selection is accuracy results from classification. Classification with four different classifier is repeated with only selected features for comparison.

D. Performance Evaluation

The classification results for all folds without feature selection (68 features) are shown in Table 3. All calculated accuracy values are higher than 90%. k-NN gives the best results while using all features. The mean accuracy is 90.59% (FLDA) and 91.03% (LDC).

After SFS is applied, the indices of the selected features are shown in Tables 4 and 5.

The accuracies for all folds after selection are shown in Table 6. FLDA has used maximum 15 features (only 22% of all features) and accuracies for all folds are increased. The mean accuracy after feature selection is 92.12% for FLDA. The mean accuracy is also amplified for LDC. It uses maximum 7 features, which is less than that of FLDA, and its mean accuracy increased by 1%. In addition to these results, mean accuracy for DT is almost the same, however it gives these approximately same results with maximum 6 features. On the contrary of these classifiers, mean accuracy of k-NN is decreased by 5% and it exposes the worst recognition. The classification results and total number of selected features for each classifier and fold are explicitly shown in Table 6.

V. CONCLUSION

In this study, four different classifiers are compared in terms of accuracy and number of selected features on the DIARETDB1 database. The aim is to find the most appropriate classifier and feature set for detecting symptoms of DR. As a conclusion, it is deduced that k-NN is superior to all other methods for detecting MA, HR, SE, HE symptoms by using 68 features. Besides, DT provides nearly same performance with all features. After the usage of selected features, DT gives nearly same results, but the accuracies of FLDA and LDC are prominently increased with considerably less features.

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Recognition of Common Lung Sounds using PCA and Support Vector Machines
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Abstract—Records are usually taken as multichannel in most of the studies about lung sounds. However, these studies which conducted as a multi-channel are not appropriate to auscultation procedure and as not suitable for the single-channel electronic stethoscope that is improved today. In this study, common lung sounds were recorded with using a single channel electronic stethoscope in accordance with auscultation procedure. Common lung sounds (healthy, rhonchus, fine and coarse crackles) were separated previously healthy and pathological data sets, then into two different data sets with four classes. Various attributes are derived using Mel-frequency cepstral coefficients which are widely used in speaker recognition. Support Vector Machine is used during the classification stage after applying the Principle Component Analysis to these features. Results that obtained from analysis have shown us that the mean of Mel-frequency cepstral coefficients which have successful results in two data sets and curve fitted to them can be used in the separation of common lung sounds.

Keywords—Electronic auscultation, Mel-frequency cepstrum coefficients, Principle Component Analysis

I. INTRODUCTION
Auscultation is the processes of listening internal sounds in a human body by using a stethoscope. Lung sound auscultation contains relevant information about the structure and function of the respiratory system [1]. Auscultation process that is used electronic stethoscope is called electronic auscultation. Lung sounds can easily be recorded through electronic stethoscopes which are developed in recent years. These records are used in the training of physicians and computerized lung sound analysis. If a physician who is not professionally well-trained cannot correctly recognize abnormalities of lung sounds and disorders. Hence, computerized lung sound analysis is important for them [2]. Computerized analysis studies can be summarized in four categories [3]:

I. Modeling: Defining a physical model for human lungs,
II. Detection-Estimation: Detection of abnormal sound components or estimation of flow cycle from pulmonary sounds data,
III. Classification: Classification of healthy and adventitious lung sound components
IV. Mapping: Building visual representations of the lung sounds based on the acoustic information.

There are many literature review studies for classification categories in last few years [4-7]. Highlights from these publications; quite different recording methods, use of improper procedures to multi-channel auscultation records, datasets are not sufficiently clear, as that of reasons understood limited the comparability of the results. Gurung et al. [4] reported that commercialization of computerized lung sound analysis devices was not suitable because of the failure of standardization between methods of studies that recording lung sounds, computer algorithms for signal analysis and statistical methods for data analysis. We believe that using a single channel electronic stethoscope during the recording step, which is in accordance with auscultation procedure will be more efficient, unlike the previous multi-channel studies. Each microphone must be carefully placed in the record, as though records that taken as multi-channel contain much more information. In addition, some of the physical characteristics of a person from who has received the record (hairy skin structure, obesity, etc.) make it difficult in multi-channel recording and directly affects the quality of the record.

In this study, the common heard lung sounds were recorded by a single-channel electronic stethoscope which is appropriate to auscultation procedure. Two different datasets were created from the records. The first dataset contains healthy and pathological data. The second dataset contains commonly heard lung sounds. Mel-frequency cepstral coefficients (MFCCs) coefficient is used to obtain features which are commonly used in speech processing. The average and standard deviation of the MFCCs and the curve fit to these two parameters are also used as features. The performance of these features is increased by applying Principle Component Analysis (PCA). Support Vector Machine (SVM) method is used in the classification step. When the results were analyzed; using the mean of MFCCs and curve fit parameters to these averages would be appropriate suggested for classification of lung sounds.

II. MATERIALS AND METHODS
A. Datasets description
Healthy and adventitious (pathological) lung sounds were described by American Thoracic Society. Commonly heard adventive lung sounds were separated into four classes as fine crackles, coarse crackles, rhonchus, and wheeze. Wheezing
can be noticed easily without the need of a stethoscope [8]. So, it was not recorded in our study. Recording set shown in Fig.1.

Fig. 1 Recording set for electronic auscultation

In the recording procedure, we used an electronic stethoscope (Thinklabs ds32a+) which has analog output and can adaptable to the digital recorder as one channel. All records are taken in stethoscope’s diaphragm mode (20-2000Hz) with 32000 Hz sample frequency. In this study, 60 healthy, 60 rhonchi, 37 fine and 18 coarse crackles (totally 175) lung sound records were taken from persons who applied to the Department of Chest Diseases, School of Medicine at KTU. All records were taken and labeled by a specialist doctor in accordance with the auscultation procedure. Two different datasets were created with utilizing from the records;

Dataset1: The first dataset consists of two different classes, including 60 healthy and 115 pathological lung sounds. These records are then divided into two approximately, 87 data is used for the test data set for 88 education.

Dataset2: Training and test data are the same as DataSet1. Unlike the Dataset1 pathological sounds are divided into three different classes in itself. Thus, the second data set is healthy, rhonchus, fine and coarse crackle was created from four different classes including crackle.

B. Mel Frequency Cepstrum Coefficients

MFCC model the frequency of human ear’s perception and one of the most preferred method for recognizing the sound. Performed studies showed that human perceived the sounds linear to the 1 kHz and logarithmic up the 1 kHz. [9,10]. Mel Frequency Cepstrum is a domain developed according to the human hearing characteristics. Physicians make an assessment of lung diseases by listening to the sounds during auscultation. Thus, MFCCs are used as feature in this study. Physiological studies have shown that human auditory system follows a linear frequency spacing below 1kHz and a logarithmic spacing above 1 kHz. The main advantage of using Mel-frequency scaling is that Mel frequency scaling is very approximate to the frequency response of human auditory systems. Fig 1. shows the block diagram of MFCC calculation process.

Fig. 2 Block diagram of MFCC calculation process.

The aim of the pre-emphasizing that is the first stage, to compensate the spectrum of the voiced regions which have a sudden drop. Pre-Emphasis Filter is carried out by correlation as in Eq.(1).

\[ y[n] = x[n] - 0.95x[n - 1] \]  

MFCC method is applied to over the short segments that are accepted have stable acoustic properties of the sound [9,10]. Therefore, the signal is divided into frames. In this study, we used 20 miliseconds frames with 50% overlapped. Each frame includes a part of the previous frame with the overlap. Hamming window which is showed in Eq. (2) is used to reduce the discontinuity at the beginning and the end of the frame. Thus, with suppressing the parts do not include information at the beginning and the end of the signal, corruption is prevented.

\[ w(n) = 0.54 - 0.46\cos \left( \frac{2\pi n}{N-1} \right), 0 \leq n \leq N - 1 \]  

After windowing the lung sound signal, Fast Fourier Transform is used to transfer these time-domain samples into frequency-domain ones. The Mel Frequency scale is defined in Eq.(3) where \( f \) is the frequency in Hz.

\[ Mel(f) = 2595. \log \left( 1 + \frac{f}{700} \right) \]

Power spectrum obtained from each windowed frame passed through a filter array of a triangular filter according to the Mel scale. In this study, Mel filter bank that includes 20 triangular filters is used and shown in Fig. 3. The sensitivity of feature vectors’ is provided to reduce with applying logarithm. Log energies of the frames are transformed to the time domain with the discrete cosine transform in the last stage. Thus, MFCCs are obtained for each frame. 12 of MFCC coefficient was calculated in this study.
A number of frames may vary depend on the length of the signal. 12 MFCCs were calculated for each frame in this study. A matrix is obtained consisting of MFCCs as a result of this process. The row number of this matrix is equal to the frame number, the number of columns is 12. The mean and standard deviation of columns of matrix and parameters of a curve fit to these coefficients have been used as feature.

C. Curve Fitting

Means and standard deviations of MFCCs in the training set analysis showed that their dispersion was exponential.

For exponential curve fitting, we used a model given by (4). These nonlinear model parameters were estimated by the Least Squares method. Using parameters of an exponential curve fitted to means and standard deviations, the number of features dropped from 12 to 2. Means of MFCCs for a sample for four different lung sounds which are in the training set of Dataset2 and curves fitted to these averages shown in Fig. 4.

\[
y = p(1).e^{p(2)x}
\]  

(4)

Standard deviations of the MFCCs and curves fitted to these standard deviations also in quite similar structure to the Fig-2. When the curves fitted to the parameters of the standard deviations of MFCCs obtained from Dataset2 training set plotted to their each other distribution of classes are illustrated in Fig 3.

![Fig. 3 Mel-Scale Filter Bank](image1)

![Fig. 4 Fitted exponential curves to means of MFCCs for a sample of training set in dataset2](image2)

![Fig. 5. Fitted exponential curves’ parameters estimated from standard deviations of MFCCs for training dataset2.](image3)

D. Principle Component Analysis

PCA is a conversion technique that ensures to reduce the less size of data set which includes many of variables related to with their each other by protecting the data as much as possible [11]. PCA provides to transport the variables which are belong to data set to a coordinate plane that is represented in lower size by discovering eigenvalues and eigenvectors of the data matrix. The reason of being useful is to create new features by finding most dominant features in the desired number from covariance matrix which is formed from data of classes. Thus, it ensures the redundancy of the data set to be minimized and at the same time maximizing the differences.

We assume that X has occurred from observation vector M of row and N \(\times\) 1 of a column as a training set data matrix. Variables would be zero means when the average vector of calculated from the mean vector education vectors are subtracted from each observation vector, and its mean is shown by X. Then the covariance matrix of zero-mean training vector (5) is calculated as in Eq. (5).

\[
C = \tilde{X}X^T = \frac{1}{M-1}\sum_{i=1}^{M}(x^i - m)(x^i - m)^T
\]  

(5)

Eigenvalues and eigenvectors of the covariance matrix are calculated using Eq. (6). C is including N \(\times\) N-dimensional matrix, \(\lambda\) is including any scalar and \(\nu\) are including a column different from zero,

\[
C\nu = \lambda\nu
\]  

(6)
The number λ that providing Eq. (6) is eigenvalues of C and v is also eigenvectors that associated with λ. Eigenvalues are ranked from small to large. G projection matrix is created with using first P number of in-line vectors that corresponding to these in-line eigenvalues. Selected eigenvectors are ranked from being the largest eigenvalues as forming rows of the matrix.

\[ G^T = \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_p \end{bmatrix} \]  

(7)

Projection of vectors that would be specified by feature vector is taken up on the G matrix as in Eq.(8).

\[ y^i = G^T x^i \quad i = 1,2, ..., M \]  

(8)

Thus, the training stage was completed. The next step is to perform a classification aimed that to make class assignments using features in training phase when an unused test data come in education.

III. CLASSIFICATION

K-fold cross-validation is used for being too much more reliable and decisive before the test results classification, in the training phase. In this method, all data is divided into subclasses for the k number approximately equal size number. This classification algorithm is trained and tested for k time. While one of the pieces was taken as test data in each time, remaining pieces creating were taken for training data. As a result, k number of different test result would have been found. The average of these results gives testing accuracy of the algorithm, according to the Kohavi’s study [12]. In our study, we chose k=5 for determining the folds.

Support vector machines (SVM) is a method developed by Vapnik and based on statistical learning theory [13,14]. The difference of SVM from the other classifiers is it’s trying to find solutions that reduce to the minimum the possibility of classification [15]. When training examples of dimensions of n are given by x and the class label is given by y written \( y_i \in \{-1,1\}, i = 1,2, ..., n \), the algorithm tries to find the best separating surface which is given as \( x + b = 0 \). In this case, the optimization problem that was written as

\[ y_i(w \cdot x + b) - 1 \geq 0, \quad \forall_i \]  

(9)

is restricted as the distance \( 2/||w|| \) is being the biggest between the nearest training surface with differential surface. Training examples that are nearest to the separator surface are represent a small subset of all of the training examples and are called as support vectors [16]. The biggest separation classifier is simple and is suggested for classification that can be separating linear. However, K is used when the data cannot be categorized as a linear space which is a core function that ensures to transition with A transformation, from X space to H-space that is data could classify as linear a larger sized.

\[ K(x,z) = \phi(x), \phi(z), \quad \forall \ x, z \in X \]  

(10)

In this study, Gaussian Radial Basis Function was used as seed function, which can be expressed as;

\[ K(x,z, \sigma) = exp \left( -\frac{||x-z||^2}{2\sigma^2} \right) \]  

(11)

Where \( x, z \in \mathbb{R}^n \) are two samples that are n-dimensional column vectors in the original space.

Multi-classed classification is made by combining the binary classifiers [13]. One-vs-one method is used for multi-class SVM in our study. k(k-1)/2 binary classifiers are created for a classification problem have k classes with considering all combinations of pairs of classes.

IV. RESULTS

MFCCs were obtained for two different datasets generated from common lung sounds. k-fold cross-validation was used for the reliability of test results in the training phase of classification. k is determined as 5, depending on the number of additional data. Following features was obtained from the MFCCs and used in both two datasets;

f1: Means of MFCCs
f2: Fitted curve to means of MFCCs
f3: Standard deviations of MFCCs
f4: Fitted curve to Standard deviations of MFCCs

The effect of the PCA analysis to classification performance also was investigated. SVM classifier was used for the classification phase. The results obtained from the analysis of Dataset1 which was consisting of healthy and pathological classes are presented in Table 1.

<table>
<thead>
<tr>
<th>Features</th>
<th>Numbers of features</th>
<th>SVM</th>
<th>PCA+SVM</th>
</tr>
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<tr>
<td>f1</td>
<td>12</td>
<td>78.16</td>
<td>100</td>
</tr>
<tr>
<td>f2</td>
<td>2</td>
<td>94.25</td>
<td>95.40</td>
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<td>f1+f2</td>
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<td>100</td>
</tr>
<tr>
<td>f3</td>
<td>12</td>
<td>72.41</td>
<td>97.70</td>
</tr>
<tr>
<td>f4</td>
<td>2</td>
<td>95.40</td>
<td>96.55</td>
</tr>
<tr>
<td>f3+f4</td>
<td>14</td>
<td>74.71</td>
<td>97.70</td>
</tr>
<tr>
<td>f1+f2+f3+f4</td>
<td>28</td>
<td>68.97</td>
<td>100</td>
</tr>
</tbody>
</table>

TABLE 1
RESULTS FOR DATASET1
When the results have investigated the performance of features that applied PCA are quite raised. The performance when PCA is applied did not change because of only two of the coefficient obtained as a result of curve fitting. The most successful results is obtained without a fail when PCA applied to \( f_1, f_1 + f_2 \) and \( f_1 + f_2 + f_3 + f_4 \) features.

<table>
<thead>
<tr>
<th>Features</th>
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<th>PCA+SVM</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_1 )</td>
<td>12</td>
<td>54.02</td>
<td>85.06</td>
</tr>
<tr>
<td>( f_2 )</td>
<td>2</td>
<td>63.22</td>
<td>58.62</td>
</tr>
<tr>
<td>( f_1 + f_2 )</td>
<td>14</td>
<td>54.02</td>
<td>85.06</td>
</tr>
<tr>
<td>( f_3 )</td>
<td>12</td>
<td>62.07</td>
<td>62.07</td>
</tr>
<tr>
<td>( f_4 )</td>
<td>2</td>
<td>63.22</td>
<td>62.07</td>
</tr>
<tr>
<td>( f_3 + f_4 )</td>
<td>14</td>
<td>60.92</td>
<td>62.07</td>
</tr>
<tr>
<td>( f_1 + f_2 + f_3 + f_4 )</td>
<td>28</td>
<td>44.83</td>
<td>81.61</td>
</tr>
</tbody>
</table>

The same features used for Dataset2 which is consisting of four classes and the results are shown in Table 2. It is understood that the results of features of \( f_1 \) and \( f_1 + f_2 \) are come forward along with the increasing number of class when Table 2 is examined. The performances were increased similarly to Table 1 when PCA is applied. The feature groups that include \( ff \) feature also were given the best results. The best results have been achieved when the mean of the MFCCs and the parameters of the curved fit them has used together when the results investigated that obtained from two Dataset.

<table>
<thead>
<tr>
<th>Features</th>
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</tr>
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<tr>
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<tr>
<td>( f_1 + f_2 + f_3 + f_4 )</td>
<td>28</td>
<td>44.83</td>
<td>81.61</td>
</tr>
</tbody>
</table>

All test data is classified as completely true for DataSet1. The confusion matrix of features of \( f_1 + f_2 \) that gives success 85.06% is given in Table-3 for Dataset2, similar to \( f_1 \) feature result. Healthy data can be classified without error and can also be seen clearly distinguished from other classes when the table examined. However, the number of records for coarse crackles and fine crackles are not enough, so more data is needed because of adequate learning not being.

V. CONCLUSION

Common lung sounds were recorded with using single-channel electronic stethoscopes which are appropriate for auscultation procedure in this study, different from multi-channel studies in the literature. The MFCCs used as a feature that has often been used in speech processing. A great performances improvement is obtained by mean of MFCCs and curve fit them. This study shows that the MFCC-PCA combination is well adapted to classify common lung sounds. Better and more accurate results can be obtained if the numbers of data, especially coarse crackles increase in future studies.

ACKNOWLEDGMENT

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REFERENCES


RFID Tag Antenna Design in Different ISM Bands for Implant Identification

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Abstract—Microstrip folded dipole antenna to use in RFID tag is presented in this study. This RFID tag antenna is designed for identifying orthopedic implant which can be placed knee or also intracorporeal. The proposed antenna consists of one pair of symmetrical folded arms for miniaturizing. The proposed antenna is designed for two different ISM (Industrial, Science and Medical) frequency bands. Firstly, for ISM band of microwave (2.4–2.48GHz), the antenna structure is printed on an FR4 substrate with dimensions of 34×12×1.515mm³ and the surface area 34×12mm² is suitable for human knee implant. Dielectric constant of used FR4 is εr=4.3 and loss tangent is 0.035. The obtained results show that the resonant frequency of the antenna is 2.45GHz with return loss -49dB and bandwidth 260MHz. The peak gain is 0.103dB at 2.45GHz which is higher than traditional intracorporeal antenna design applications. For the second ISM band of UHF (Ultra high frequency) (860–960 MHz), the tag antenna design is conducted on FR4 substrate with 1.48 mm thickness with surface dimensions of 37.2×12mm² and the same dielectric constant is εr=4.3 and tangent loss is 0.035. In UHF band, the simulated resonant frequency is 888MHz. In this frequency, antenna’s return loss is -25.93dB and bandwidth is simulated for 74MHz. The peak gain of the antenna is -10.7dB. All folded dipole antennas are designed and simulated by CST Microwave Studio.

Keywords—Implant Identification, RFID Tag, Folded Dipole Antenna, Orthopedic Implant.

The most significant part is tag antenna in a RFID system, because the material and the size of the antenna can be varied according to the application field. For example, a RFID system can be used in human body, on a metal object or inside a materiel which have different dielectric losses. Therefore antenna design parameters as its geometry can vary according to its application medium. Commonly, most applications require the tag antenna be compact in size, low cost and easy to fabricate.

Orthopedic implant is a kind of joint implant to replace severely injured or diseased joints for people who suffer from joint problems and aim to bring those people back to a normal life [5]. Each knee implant system is made up of three components as seen on Fig. 1: femoral component, polyethylene component, tibial component. Nowadays these implants are very common in orthopedic surgeries for patients who have severely injured joints. The total number of knee and hip replacement surgeries per year in US keeps increasing in the recent years and will hit 3.48 million in 20 years [6].

This study, as general manner, suggests RF identification of implants while in the human body by designing the most important part so as antenna of RFID tag. Tag antenna has been designed for knee implant which is orthopedic implant (Fig. 1). As in different works, tag antennas usually are placed on polyethylene part.

I. INTRODUCTION

Nowadays, Radio Frequency Identification (RFID) technology has been widely use in various and different areas such as logistic, security, library, airline, military, animal forms, sports, healthcare and other areas [1].

A typical RFID system is made up of a tag and a reader: a digital data processing integrated circuit (IC) device called RFID tag is combined with an antenna, a reader that communicates with the tag antenna by means of electromagnetic waves and a host data storing system embodies the information of the identified item and communicates with other remote data processing systems [2].

The RFID systems use frequency bands of low-band range 125–134kHz, high frequency (HF) 13.56MHz ultra high frequency (UHF) 860–960MHz, microwave 2.45GHz, super high frequency 5.8 GHz and ultra-wide band (UWB) 3.1-10.6GHz [3, 4].

Fig. 1 Parts of orthopedic knee implant [7].
When the implant replacement surgery has finished, doctors and surgeons have difficulty to observe and obtain the detailed information of the implant. So that, especially orthopedic implant placement and modification stage, information within the implant to move with the patient while making this process, reduce cost and time, improve data reliability, is planned to be used RFID system [5]. Existing method for implant identification have some problems. For example information about patient or implant is not stored with implant; mostly it is stored in archives, which can raise the risk of data loss. Another case, many hospitals still use paper based archives to keep the patient history whose management is a huge cost and hardship. The other, it takes much time to search for the implant and patient information, which does not only increase the risk of mistakes but also increases the cost [8].

As known, active RFID tags have both large antenna size and constantly radiated electromagnetic waves harmfully. The proposed solution should be a battery free implantable RFID tag attached on the orthopedic implant. Thus, tag antenna will work only within reader antenna’s electromagnetic wave energy. This design has been achieved with a microstrip folded dipole antenna which can be placed on the knee implant size. Microstrip folded dipole antenna is widely used in the applications of Wireless Local Area Network (WLAN) and 2G wireless communication system as the structure of G-shape. In this study, this structure is introduced as a new method of reducing the size of tag antenna because of limits of knee implant size. In this way RFID tag antenna can be implemented easily on the orthopedic implant to identify patient, implant and surgery information [9].

In this study two tag antennas have been designed in the same geometry but in two different operation frequencies in two different ISM bands as 2.45GHz microwave and 860–960MHz UHF band to select suitable solution. It has been decided how the antenna size changes and optimum antenna design is implemented in intracorporeal using simulation results. Primary aim is reducing the size of the dipole antenna here. Therefore, design of microstrip folded dipole antenna is experimented to use in intracorporeal applications. Finally, these two designed antennas have been compared for antenna size, frequency, gain, return loss to get clearly understood tag antenna can be placed on knee implant.

II. TAG ANTENNA DESIGN

The tag antenna design is the most critical part of RFID system. Here, the design of tag antennas may be varies depending of application region. For implant identification, in human body, the dimension of tag antenna must be limited with the implant size.

Operating frequency (f), speed of light (c) and, effective dielectric constant (ε_{eff}) are requisite to calculate length of a microstrip dipole antenna. Fig. 2 shows the geometry of traditional microstrip dipole antenna. Half of the wavelength is equal the length (L) of the microstrip dipole antenna. The following equations 1 and 2 are used for calculate length of a traditional microstrip dipole antenna like Fig. 2.[10]

\[ \varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} \left[ \frac{1 + \frac{2}{\varepsilon_r}}{1 + \frac{2}{\varepsilon_r}} \right]^{\frac{1}{2}} \]  

\[ \lambda = \frac{c}{f \sqrt{\varepsilon_{eff}}} \]  

- ε_{eff} = Effective dielectric constant,
- ε = Relative dielectric constant,
- T = Thickness of microstrip material,
- Y = Width of microstrip dipole arm ,
- f = Operating frequency,
- c = Speed of light,
- λ = Wavelength.

Equation 1 shows how can calculate effective dielectric constant (ε_{eff}). This parameter is needed to calculate wavelength in equation 2. So the length of microstrip dipole antenna can find simply.

Fig. 2 The geometry of traditional microstrip dipole antenna

Fig. 3 shows the geometry of RFID tag antennas which is suggested for knee implant identification in this work. In this geometry, A and B terminals are connected with two radiation arm and shorting strip. The width (Y1) of the radiating arm is adjusted at 2.7 mm for centre frequency of both 2.45GHz and 888MHz. The microstrip folded dipole antenna consists of two radiating arms separated by a 2.4mm width slot (s). This slot is used for compact tag chip which involve the information about knee implant.

Fig. 3 The geometry of microstrip folded dipole antenna.

The width (d) and length (w) values of the shorting strip are fixed at an optimum ratio to provide a good impedance matching. Table 1 tabulates the optimum dimensions of the
tag antenna which can be placed on knee implant in two different frequencies. The antenna is fed by 50Ω coaxial cable from points A and B by using discrete port type in CST Microwave Studio. Microstrip folded dipole antenna has symmetrical geometry, so that feeding points can be selected from A to B or opposite way.

Dimension of tag antenna have to be compact to place on knee implant which is in intracorporeal. For this reason conventional dipole antenna is folded and takes the smaller size geometry as in Fig. 3. The length of the conventional dipole antenna is 168mm working at 888MHz. The proposed folded dipole antenna is reduced in length size with ratio of 77% according to conventional dipole antenna. For 2.45GHz this ratio is calculated as 48%. As a result, this structure of dipole antenna reduces the size of antenna and provides optimum antenna geometry to place on knee implants.

### III. SIMULATION PLATFORM

Signal attenuation occurs when the RF signal penetrates in biological tissue as known [11]. Simulations have to be made according to measurement platform to take actual outcomes. So simulation platform is designed for actual measurements. All antenna designs are simulated with CST Microwave Studio according to this model as shown in Fig. 4.

### TABLE I

<table>
<thead>
<tr>
<th>Antenna Length Parameters (mm)</th>
<th>Antenna 1 UHF (888MHz)</th>
<th>Antenna 2 ISM (2.45GHz)</th>
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<tbody>
<tr>
<td>$X_1$</td>
<td>37.2</td>
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<td>$X_2$</td>
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</table>

III. SIMULATION PLATFORM

Signal attenuation occurs when the RF signal penetrates in biological tissue as known [11]. Simulations have to be made according to measurement platform to take actual outcomes. So simulation platform is designed for actual measurements. All antenna designs are simulated with CST Microwave Studio according to this model as shown in Fig. 4.

Fig. 4 Simulation model of RFID tag antenna in CST

Biological tissue and polyethylene material reduce RF signal efficiency and downscale dimensions of tag antenna [11]. Layer of skin can be chosen form CST library. But polyethylene material has to be added in CST to make simulation realistically. For this simulation dielectric constant of polyethylene is selected 2.6 and loss tangent is added 0.00031 [12].

IV. RESULTS

Fig. 5 shows that the resonant frequency of Antenna 1 is 888MHz in UHF band. At this frequency, the return loss $|S_{11}|$ is -25.93dB and bandwidth is taken nearly 74MHz.

![Fig. 5 The characteristic of $|S_{11}|$ (return loss) for 888 MHz](image)

Fig. 6 shows simulated return loss of proposed Antenna 2 which works at 2.45GHz resonant frequency. This simulation result shows that the resonance frequency of the tag antenna is at 2.45GHz with return loss -48.50dB and bandwidth 277MHz.

![Fig. 6 The characteristic of $|S_{11}|$ (return loss) for 2.45 GHz](image)
Fig. 7 and Fig. 8 show that simulated radiation patterns at 888MHz and 2.45GHz. The peak gain of the microstrip folded dipole antenna is seemed -10.7dB for Antenna 1.

![Simulated radiation patterns](image)

Fig. 7 Simulated radiation pattern at 888MHz (Antenna 1)

Fig. 8 shows that the peak gain of Antenna 2 at 2.45GHz is 0.99dB. This gain is satisfactory and higher than traditional dipole antenna in intracorporeal applications.

![Simulated radiation patterns](image)

Fig. 8 Simulated radiation pattern at 2.45GHz (Antenna 2)

As a summary in results section, Table II shows comparison of frequency, gain, bandwidth, and return loss of Antenna 1 and Antenna 2. Antenna 2 has good advantages than Antenna 1 taken from simulation results to be realized in the future.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna 1</td>
<td>888</td>
<td>-10.7</td>
<td>74</td>
<td>-25.93</td>
</tr>
<tr>
<td>Antenna 2</td>
<td>2450</td>
<td>0.99</td>
<td>277</td>
<td>-48.50</td>
</tr>
</tbody>
</table>

V. CONCLUSION

This paper proposes microstrip folded dipole antenna to identify an implantable RFID tag to embed on orthopedic knee implants. For this purpose, two tag antennas have been designed in the same geometry but in two different operation frequencies in two different ISM bands as 2.45GHz microwave and 860–960MHz UHF band. The simulation results are presented that the antenna designed at 2.45GHz is suitable and realistic intracorporeal designs. Especially, return loss, bandwidth, gain values and patterns sustain this antenna can be realized.

For the future work, selected antenna will be printed and measured in the phantom medium.

ACKNOWLEDGMENT

This work was supported by The Department of Scientific Research Projects in Süleyman Demirel University named as “RFID System Design for Implant Identification” and in Turkish “Implant Tanımlama için RFID Sistem Tasarımı” [Project Number: 4256-YL1-15].

REFERENCES

Classification of Structural MRI for Detecting Alzheimer’s Disease

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Abstract—Alzheimer’s Disease (AD) is a pathological form of dementia that degenerates brain structures. AD affects millions of elderly people over the world and the number of people with AD doubles every year. Detecting AD years before the effects of disease using structural magnetic resonance imaging (MRI) of the brain is possible. Neuroimaging features that are extracted from the structural brain MRI can be used to predict AD by revealing disease related patterns. Machine learning techniques can detect AD and predict conversions from mild cognitive impairment (MCI) to AD automatically and successfully by using these neuroimaging features. In this study common structural brain measures such as volumes and thickness of anatomical structures that are obtained from The Open Access Series of Imaging Studies (OASIS) and made publicly available by https://www.nmr.mgh.harvard.edu/lab/mripredict are analysed. State-of-the-art machine learning techniques, namely support vector machines (SVM), k-nearest neighbour (kNN) algorithm and backpropagation neural network (BP-NN) are employed to discriminate AD and mild AD from healthy controls. Training hyperparameters of the classifiers are tuned using classification accuracy which is obtained with 5-fold cross validation. Prediction performance of the techniques are compared using accuracy, sensitivity and specificity. Results of the system revealed that AD can be distinguished from the healthy controls successfully using multivariate morphological features and machine learning tools. According to the performed experiments SVM is the most successful classifier for detecting AD with classification accuracies up to 82%.

Keywords—Alzheimer’s Disease, neuroimaging, structural MRI, multivariate analysis, image classification, machine learning techniques

1. INTRODUCTION

Alzheimer’s disease (AD) is the most common form of dementia and affects millions of people around the world. AD is not a curable disease but the progress of the disease can be slowed down if it is detected in an early stage. AD causes pathological changes on the brain. These changes can be detected before clinical symptoms begin. Mild cognitive impairment (MCI) is a stage before AD and healthy aging. MCI is likely to turn into AD. 12% of people with MCI convert to AD in a year and 80% of people with MCI convert to AD after 6 years. [1-4].

Structural magnetic resonance imaging (MRI) is a non-invasive imaging technology that is used successfully for detecting AD. MRI is sensitive to the degenerations that AD caused on the brain such as tissue damage or loss. Hippocampus, entorhinal cortex and posterior cingulate cortex are the brain regions that are most effected from AD. These brain regions are also predictive of transition of MCI to AD. Tissue loss related to AD correlates well with the scores of the clinical cognitive tests that reveal a cognitive decline. High resolution T1-weighted MRI is the best tool to detect hippocampal atrophy. Structural brain measures such as volumes and thickness of anatomical structures are obtained from the T1-weighted MRI and these measures are used to detect any degenerations on the brain regions. MRI-based estimates help to early diagnose of the AD that can be used to slow down the progress of the disease [5-6].

Computational methods are required to predict subjects with AD and subjects who is under risk to show cognitive decline that can turn into AD in years. Machine learning methods are used for this purpose over years to detect AD and predict conversions from MCI to AD. SVM is one of the most popular method for classification of AD vs normal control (NC) and AD vs MCI. Magnin et al. proposed a method to classify AD patients and NC by using a whole-brain MRI analysis. They have extracted features by using a histogram analysis. They have utilized characteristics of the distribution of the brain tissues such as gray matter (GM), white matter (WM) and cerebrospinal tissue (CSF) that gives information about neurodegenerative disease like AD [7]. Cocoso et al. have used pruning strategy to customize a training set that will not affected by anatomical variability and pathology. They have used prior tissue probability maps in a standard stereotaxic space to generate a set of samples, then they reduced fraction of incorrectly labelled samples in this set and used a supervised kNN classifier for classifying the MRI scans using the corrected set of samples [8]. Amoroso et al. utilized BP-NN for classification of 288 subject to discriminate AD vs NC and AD vs MCI. Their method includes three steps. First, they applied rigid registration and histogram based equalization to the MR images. Then they have calculated important features like hippocampal volume or its thickness from a volume of interest that contains both the left and right hippocampi regions. Finally, they utilized a BP-NN for classification and obtained 0.81 overall accuracy [9].

In this study, structural MRI is classified for detecting AD using machine learning methods and structural brain measures such as volumes and thickness of anatomical structures. We utilized SVM, kNN and BP-NN for classification task with 5-fold cross validation.
II. MATERIALS AND METHODS

A. Data

T1-weighted cross-sectional structural brain MRI scans of the OASIS database [10] are used to extract structural brain measures of anatomical structures and made publicly available at https://www.nmr.mgh.harvard.edu/lab/mripredict by Sabuncu and Konukoglu [6]. These morphometric brain features including volumes and thickness of the anatomical structures of the brain are analysed in this study to classify AD and mild AD. 190 subjects from the OASIS database is used to obtain brain measures for binary classification. These subjects were the ones that the automatic image processing steps of FreeSurfer (https://freesurfer.nmr.mgh.harvard.edu) is successful. FreeSurfer is a brain MRI analysis software that is used widely and freely available. Table I summarizes the demographic features of the data.

<table>
<thead>
<tr>
<th>Variable</th>
<th>N per group</th>
<th>Age (Mean±Std)</th>
<th>% Female</th>
<th>Number of sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD</td>
<td>25</td>
<td>77.5±6.8</td>
<td>72</td>
<td>1</td>
</tr>
<tr>
<td>AD mild</td>
<td>70</td>
<td>75.9±7.3</td>
<td>68.6</td>
<td>1</td>
</tr>
</tbody>
</table>

Table I. Features of the Dataset

Fig 1. T1-weighted cross-sectional brain MRI scans of subjects with (a) AD, (b) AD mild and (c) NC.

Subjects who has clinical dementia rating (CDR) >=1 was defined as AD and CDR>0 as AD mild. AD mild include subjects suffering from MCI and not clinically demented. Fig 1 shows sample MRI scans from the OASIS database belonging to the subjects with AD, AD mild and NC whose subject numbers in the database are OAS1_0003_MR1, OAS1_0035_MR1 and OAS1_0062_MR1, respectively.

B. Feature Sets

Four sets of morphological brain features are used for prediction of AD that are obtained using FreeSurfer. Details of feature extraction process can be found at [6]. The brief explanation of the feature sets is given below.

1) Feature Set 1 (aseg): This feature set includes volumes of the 45 anatomical structures. Because of head size variations, these volumes are normalized with each subject’s intracranial volume.

2) Feature Set 2 (aparc): This feature set includes 34 average thickness measurements within the cortical parcellations per hemisphere.

3) Feature Set 3 (aseg + aparc): The union of the aseg and aparc feature sets is a 113 dimensional vector.

4) Feature Set 4 (thick): 10,242 vertices per hemisphere is calculated. The cortical thickness values are sampled onto the fsaverage5 template. These values are smoothed on the surface by using an approximate 5 mm Gaussian kernel.

C. Support Vector Machines

SVM is the most popular binary classification algorithm used for the prediction of diseases from the structural MRI [4, 11]. SVM learns class differences in a supervised manner by using labelled training samples. SVM classifies a binary labelled data by mapping the data to a very high-dimensional feature space. A separating hyperplane is constructed in the feature space that is used as a decision surface to separate the training data. This hyperplane is defined as \( w^T x + b = 0 \), where \( b \) is the bias for the input vector \( x \) and \( w \) is the weight vector. Informative subsets of the training data are used as support vectors to determine the decision surface. The margin between support vectors are minimized by maximizing \( \| w \| \). Classes are determined by two subspaces that are obtained after training. Fig. 2 illustrates support vectors and decision surfaces of a SVM [4, 12].

Fig 2. Support vectors and decision surface.

There are three different kernels namely polynomial, radial basis function (RBF) and sigmoid, that are used for nonlinear feature mapping of the SVM. In this study, sequential minimal
with 5 grid search is employed for selection of the best parameter set for all folds. Error function is computed relative to the hidden units by backpropagation. BP algorithm adjusts the weights that will map input to the output by updating their weights using connection from the previous layer. The final layer calculates the output.

### D. K-nearest Neighbour Algorithm

kNN is a supervised classifier that computes closest \( k \) training samples of the data point that will be classified in the feature space. The data is classified with the label of the most representative neighbour among the closest ones that are detected by kNN. kNN which is a non-parametric classifier learns from the training data. Large size of the training data increases the prediction performance of the kNN by estimating the true class distributions in feature space [8]. The value of \( k \) that is the number of nearest neighbours to the classified data is the key parameter for the algorithm.

### E. Neural Network

Neural networks are used widely in medical image classification task since there is no need any information related to the probability distribution of the data and a priori probabilities of different classes [14, 15]. Backpropagation (BP) uses a feed-forward and supervised learning algorithm. Feed-forward NN has three main layers. First layer is the input layer. Then there are hidden layers. Each hidden layer has a connection from the previous layer. The final layer calculates the output of the NN. Each layer consists a number of neurons that will map input to the output by updating their weights using gradient descent learning rule. BP algorithm adjusts the weights of the neurons in the steepest descent direction that the performance function decreases most rapidly. Gradient of the error function is computed relative to the hidden units by back propagation of the error.

### III. RESULTS AND DISCUSSION

Subjects that has AD (N=25) and mild AD (N=70) are discriminated from NC subjects (N=95) by using four different sets of structural brain measures [6] that reveals the degeneration of the AD on the brain which leads to classify normal and abnormal brain scans. SVM, kNN and BP-NN are used for the classification. 5-fold cross validation is applied for all classification tasks to assess the generalizability of the performance. The number of cases and controls were the same for all folds. Results of the classification are evaluated in terms of their accuracy, sensitivity and specificity.

SMO learning function and RBF kernel is employed for SVM. \( C \) and \( \sigma \), the two parameters of the RBF kernel should be determined carefully for a successful classification of SVM. A grid search is employed for selection of the best parameter set with 5-fold cross validation to reduce the selection-related bias. A coarse grid is generated by growing values of \( C = [2^0, 2^3, ..., 2^{15}] \) and \( \sigma = [2^{-5}, 2^{-4}, ..., 2^{15}] \). A finer grid search is performed after identifying a better region on the coarse grid [16].

\[
K(x, x') = \exp \left( -\frac{\|x-x'\|^2}{2\sigma^2} \right)
\]

\[ (1) \]

#### Table II

<table>
<thead>
<tr>
<th>Feature Set</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
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<tr>
<td></td>
<td>AD Mild</td>
<td>AD Mild</td>
<td>AD Mild</td>
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<td>aseg</td>
<td>0.821</td>
<td>0.800</td>
<td>0.843</td>
</tr>
<tr>
<td>aparc</td>
<td>0.657</td>
<td>0.760</td>
<td>0.729</td>
</tr>
<tr>
<td>aseg+aparc</td>
<td>0.743</td>
<td>0.800</td>
<td>0.743</td>
</tr>
<tr>
<td>thick</td>
<td>0.671</td>
<td>0.760</td>
<td>0.643</td>
</tr>
</tbody>
</table>

### TABLE II CLASSIFICATION ACCURACIES OF THE SVM

Gradient descent learning algorithm is used for training of the BP-NN. One hidden layer with 5 neurons are trained with 5-fold cross validation with 1000 epochs at each fold. These parameters are determined empirically according to their classification performance. Results that are obtained using BP-NN are given in Table IV. OoM means out of memory that BP-NN could not converge up to 1000000 epochs. Different number of hidden layer neurons and learning algorithms did not help BP-NN to converge using thick feature set. The most successful feature set was aseg for the BP-NN for both AD and mild AD cases.

#### Table III

<table>
<thead>
<tr>
<th>Feature Set</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AD Mild</td>
<td>AD Mild</td>
<td>AD Mild</td>
</tr>
<tr>
<td>aseg</td>
<td>0.657</td>
<td>0.800</td>
<td>0.471</td>
</tr>
<tr>
<td>aparc</td>
<td>0.643</td>
<td>0.740</td>
<td>0.471</td>
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<tr>
<td>aseg+aparc</td>
<td>0.643</td>
<td>0.740</td>
<td>0.471</td>
</tr>
<tr>
<td>thick</td>
<td>0.614</td>
<td>0.680</td>
<td>0.329</td>
</tr>
</tbody>
</table>

### TABLE III CLASSIFICATION ACCURACIES OF THE kNN

#### Table IV

<table>
<thead>
<tr>
<th>Feature Set</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AD Mild</td>
<td>AD Mild</td>
<td>AD Mild</td>
</tr>
<tr>
<td>aseg</td>
<td>0.750</td>
<td>0.800</td>
<td>0.743</td>
</tr>
<tr>
<td>aparc</td>
<td>0.621</td>
<td>0.740</td>
<td>0.543</td>
</tr>
<tr>
<td>aseg+aparc</td>
<td>0.693</td>
<td>0.700</td>
<td>0.686</td>
</tr>
<tr>
<td>thick</td>
<td>OoM</td>
<td>OoM</td>
<td>OoM</td>
</tr>
</tbody>
</table>
Performance comparison of the classifiers and the feature sets is given in Fig. 3. SVM was the most successful classifier independent from the feature set and the aseg was the most successful feature set independent from the classifier type. The highest classification accuracy is achieved with the combination of the SVM and the aseg feature set. Classifying AD mild was more difficult then classifying AD since the disease related changes on the brain is more evident in the AD case.

REFERENCES
Examination and Classification of Robots Used at the Health Sector, and Some Recommendations for Disadvantaged Circumstances

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Abstract— Nowadays robotic systems are used in many fields. One of them is the health sector. Surgical robots which are used in the health sector are physically similar to each other but their purposes are quite different. Also surgical robots have major mechanically differences.

Using of robotic systems in surgical procedures is revolutionary. Robots are taking the role of the surgeon at simple surgical procedures.

In addition to this, in recent years rehabilitation robots have gained importance at the health sector. These robots used in physical therapy significantly facilitates the task of both patients and medical personals. In addition, robotic solutions found an important place also at prosthetic technology.

In this study, used from past to present robotic systems at the health sector are examined, made classification depends on the purpose, advantages and disadvantages of this robots have been investigated. Some advices given by us for situations considered to be negative.

Keywords— Surgical robots, rehabilitation robots, prosthetic technology, health sector

I. INTRODUCTION

Today robots are used in the health sector as an important adjunct. Especially tele-operation robots considerably facilitating remote intervention. In this study, some of surgical robots are examined and classified.

II. CLASSIFICATION OF SURGICAL ROBOTS

Medical robots are classified under three main headings as a Assistive Technologies, Surgical Robotics and Other Surgical Robots.

A. Assistive Technologies

Robots and machines which improve the quality of life of disabled and elderly people, mainly through increased personal independence.

1) Prosthetic Devices:
   - Advanced under actuated multi-degree of freedom hand for below elbow amputees
   - Fingertip pressure built-in sensors
   - Neuro prosthetic electrodes implanted in or around the nerve stump to detect the user’s volitional commands and to feedback sensations from the pressure sensors (and others)
   - Implant custom stimulator/amplifier

Figure 1: Evolution of the active hand prostheses (from EURON Roadmap, 2004)

Figure 2: Cyberhand Advanced Prosthetic Hand Advanced (EU Project coordinated by SSSA, Pisa)

Figure 3: C-Leg (Otto Bock Health Care, Inc., USA)
2) Orthotic / wearable devices

(a)  
(b)  
(c)  

Figure 4a, 7b, 7c. Wearable devices

3) Robotic Aids

Figure 5 Robot MANUS (Exact Dynamics BV, The Netherlands)

Figure 6 VAID EU project (Coordinated MOVAID by SSSA, Italy)

4) Personal Assistants

Figure 7 Companion in Touch Health, Goleta, CA, USA)

5) Rehabilitation robotics

Rehabilitation Robotics has been defined a special branch of robotics which focuses on machines that can be used to help people recover from severe physical trauma or assist them in activities of daily living. This field has evolved from a more common field known as Rehabilitation Engineering. Rehabilitation Engineering is closely related to physical therapy and it utilizes its three main focus areas. The three main areas of physical therapy are the cardiopulmonary, neurological, and musculoskeletal.

B. Surgical Robotics

1) Neurosurgery Robots

Figure 10 Neuromate (IMMI/ISS), 1996

Figure 11 Neurobot (Imperial College)
2) Minimaly Invasive Surgery (MIS) Robots

Figure 12 ZEUS (Computer Motion), 1998

C. Other Surgical Robots

1) Radiological Robots

Figure 18 CyberKnife

2) Ultrasonic Robots

Figure 19 Ultrasonic robots

3) Remote Center of Motion Mechanisms

Mechanisms that the part of surgical robot which make the main work in surgical operation. Especially uses for the purpose of laparoscopy at MIS.
III. CONCLUSIONS

After examination it was seen that especially the MIS robots fill too much space in the operating room. In addition, contain too many mechanical and electronic components of this robot, increases the possibility of failure.

Long and complex control algorithms of this robots are disadvantages in manufacturing of this robots.

For remotely controlled robots, communication delays are negatively affects the operation.

In particular, the high sensitivity of the brain and eye surgery is a problem that must be overcome to large-bodied robots. To overcome the problems such as cost, precision, communication, minimizing the robot body is one of the solutions. Use of RCM mechanism in operation will reduce both costs and time of operation.

ACKNOWLEDGMENT

We owe a debt of thanks to Selcuk University.

REFERENCES

[1] Rui Cortesão, University of Coimbra Electrical and Computer Engineering Department Medical Robotics 2005/06.
The Diagnosis and Estimate of Chronic Kidney Disease Using the Machine Learning Methods

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Abstract— Chronic kidney disease is a prolonged disease that damages the kidneys and prevents the normal duties of the kidneys. This disease is diagnosed with an increase of urinary albumin excretion lasting more than three months or with significant reduction in a kidney function. Chronic kidney disease can lead to complications such as high blood pressure, anemia, bone disease and cardiovascular disease. In this study we have investigated to determine the factors that decisive for early detection of chronic kidney disease, launching early patients treatment processes, prevent complications resulting from the disease and predict of disease. The study aimed diagnosis and prediction of disease using the data set that composed of data of 250 patients with chronic kidney disease and 150 healthy people. First, the chronic kidney disease data was classified with machine learning algorithms and then training and test results were analysed. The estimation results of chronic kidney disease were compared with similar data and studies.

Keywords— Chronic Kidney Disease, Machine Learning, Classification.

I. INTRODUCTION

Today, technology is progressing day by day and the entry into almost every aspect of life and the data is obtained and stored in various areas. There are examples in every area of life which data is available and stored such as to keep track of income and expenses of the companies, to storage of information of students in school, to keep information that obtain as a result of personal work. Although often created large data sets used to store data, it is possible to convert data into information through a variety of operations on data and predict the future by the available data. Generally, techniques used for the conversion of the data according to the purpose information processing is known as data mining. By the application in daily life of information obtained data mining large gains can be achieved [1].

One of the areas where the application of data mining is the health field. In this area, determining in advance of possible illness, identifying the different cases where the disease associated with the forward-looking assumptions and patient conditions is possible by the studies on the generated data.

The job of the kidneys is to filter the blood. All the blood in your body passes through the kidneys several times a day. Kidneys have a responsibility to throw waste from the body, to control fluid balance and to regulate the electrolyte balance. The system is not working properly kidney stones and kidney failure may occur here.

Factors which increase the risk of kidney disease are diabetes, hypertension, smoking, obesity, heart disease, kidney disease in the family, alcohol, drug abuse, drug overdose, age, race, sex, symptoms of kidney disease, urinary function changes, difficulty during urination, blood in the urine, back or back pain at the edges, fatigue, dizziness, lack of attention, always feeling cold, rash-itch, ammonia breath, metallic taste, nausea, vomiting and shortness of breath [2].

Chronic renal disease is a long-term disease that is being damaged kidneys and preventing them from doing actions which the normal duties of the kidneys such as cleaning the blood from harmful substances, the body maintain fluid balance, blood pressure regulation and hormone production. The disease is diagnosed with a significant reduction in urinary albumin excretion, increased or renal function for more than three months. This disease can lead to complications such as high blood pressure, anemia, bone disease and cardiovascular diseases [3].

Currently, there are many programs which host data mining algorithms. Some of these programs and software are Weka, R, Orange, Kniece etc. These programs generally contain the same algorithms. But algorithms vary functioning forms of information because the algorithm authors are different and algorithms are developed. In our study, the support vector machine and decision tree algorithms of Weka program are used. Support vector machine is one of the simplest and effective methods used for classification. The decision tree algorithm is one of the machine learning methods and classification, is represented by tree branches and leaves forming a simple tree structure [4].

The study is to investigate the predictability of the disease. Using a variety data of chronic kidney patients and normal patients. In this study, we used a data set of 400 persons obtained from the “UCIMachine Learning Repository” data warehouse which is including the information of patients and people without [5].

II. LITERATURE REVIEW

Vijayaranis forecast kidney disease by using Navie Bayes and support vector machine algorithms. Mainly in the research, focused on finding the best classification algorithm according to the classification accuracy and execution time performance factors. It was found that the performance of the support vector machine algorithm to be better than Naive Bayes classifier from the experimental results [6].
Srinivasa has developed a dialysis support system with a kidney failure data and decision tree algorithm [7].

Kaladharhas achieved 97% success with J48 algorithm and 98% success with RandomForest algorithm in recognition of kidney stones with Weka[8].

Zadehhas achieved 80.85% success with WJ48 algorithm and 85.11% success with W Simple Cart algorithm for early detection of dialysis with Weka[9].

Hyaribus the decision tree algorithm in the practice of chronic renal disease with Weka[10].

Song, has achieved 80% success with decision tree algorithm for renal failure disease using Weka[11].

Kumarhas achieved 96% success in identifying kidney stones using multi-layered network structure neural network algorithm with [12].

III. METHODOLOGY

A. Dataset

A dataset that usedis composed of data of 24 different variables that obtained from 250 patients with chronic kidney and obtained from 150 patients with non within 2 months from a hospital. The presence of 24 various tests measure to each patient is important in this data set in terms of demonstrating the applicability of conclusions derived from the results of studied to daily life.

These data and properties are shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>PATIENT DATA AND UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-age</td>
<td>age</td>
</tr>
<tr>
<td>2-bp</td>
<td>blood pressure</td>
</tr>
<tr>
<td>3-sg</td>
<td>specific gravity</td>
</tr>
<tr>
<td>4-al</td>
<td>albumin</td>
</tr>
<tr>
<td>5-su</td>
<td>sugar</td>
</tr>
<tr>
<td>6-rbc</td>
<td>red blood cells</td>
</tr>
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<td>7-pc</td>
<td>pus cell</td>
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<td>pus cell clumps</td>
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<tr>
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</tr>
<tr>
<td>21-cd</td>
<td>coronary artery disease</td>
</tr>
<tr>
<td>22-appet</td>
<td>appetite</td>
</tr>
<tr>
<td>23-pec</td>
<td>pedal edema</td>
</tr>
<tr>
<td>24-an</td>
<td>anemia</td>
</tr>
<tr>
<td>25-class</td>
<td>class</td>
</tr>
</tbody>
</table>

As shown in Table 1, patient data is also included age, blood pressure and appetite information in addition to various information of assays. The values and units of this data varies according to the type of data. 1, 2, 10, 11, 12, 13, 14, 15, 16, 17 and 18 of the variables in data are get units specified numerical values; 3, 4 and 5 of the variables in data are get specific numerical values; and others consist of the specified non-numeric values and the initial values are written in parenthesis next to the data. There is also a 25th variable in the data of the person that to hold the information “ckd” if a person patient and “notckd” if a person not the patient.

B. Support Vector Machine

There are many algorithms can be used for classification in Weka software. Support vector machine is one of the very effective and simple methods that used for classification. Simply, support vector machine is an algorithm that working the method of to draw a line in the plane between the two groups and the separation of these two groups. In Figure 1, separating the groups from each other by the algorithm is shown.

In Figure 1 the first verify are drawn two groups identified the closest element to each other, representing these elements, for to separate the two groups placed in a two-dimensional plane by support vector machine. The process of separating two different groups from each other is maintained for determining the correct point on the equidistant two lines drawn between the two towards. In the Weka, SMO (Sequential Minimal Optimization) algorithm is using like the support vector machine algorithm[14].

C. Decision Tree

In the decision tree algorithm method, the class labels are level of the tree leaves, leading to the leaves and the process on start arms are expressed forming a tree structure[15]. The tree structure as a result of the decision tree algorithm is shown in Figure 2.
Analysing the test results in Table 2; for both algorithms, it was found that the error values of from Test-1 results are lower than the error values of from Test-2. Because of the data size used to train the algorithm in Test-1 is larger than the data size of the Test-2 process; algorithms are better educated, forecast accuracy higher than Test-2 and forecast transactions are also lower as a result of the error values in the Test-1 processing. Therefore it the magnitude of the training data affects estimation process. Kappa statistic values are also outside the error values in the table. To be close to 1 of this value indicates the accuracy of the estimation process. The reliability and validity of the estimate decreases when the kappa statistic closer to zero. The decision tree formed in the Test-1 results of J48 algorithm is shown in Figure 3.

FIGURE III. The Decision Tree Formed in the Test-1 Results of J48 Algorithm

<table>
<thead>
<tr>
<th>Result Name</th>
<th>J48</th>
<th>SMO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test-1</td>
<td>Test-2</td>
</tr>
<tr>
<td>Percentage of Correct Classification</td>
<td>100 %</td>
<td>91.6667 %</td>
</tr>
<tr>
<td>Kappa Statistic</td>
<td>1</td>
<td>0.827</td>
</tr>
<tr>
<td>Mean Absolute Error</td>
<td>0.0226</td>
<td>0.1547</td>
</tr>
<tr>
<td>Mean Square Error</td>
<td>0.0837</td>
<td>0.2753</td>
</tr>
<tr>
<td>Relative Absolute Error</td>
<td>4.8492 %</td>
<td>34.292 %</td>
</tr>
<tr>
<td>Absolute Relative Root Square Error</td>
<td>17.4751 %</td>
<td>55.3729 %</td>
</tr>
</tbody>
</table>

When examined the decision tree in Figure 3; it is observed that begins with the capability of serum creatinine (sc). Because the leaves of decision trees are ranked according to earnings criteria, it can say that the first decisive feature in the estimation process is this feature. Other features that make up the branches of the decision tree are also of importance for the estimation process, respectively. Each leaf is divided into branches by >, < = and <= operations. The last leaf of the branches, it is reaching the (ckd) value or (unckd) value if the people are patients or not patients. The first number listed in parentheses next to this value illustrates the total weight of examples in the leaves, the second number indicates the weight of the incorrect classification. In addition, in the estimates, the total number of leaves of the created tree (Number of Leaves), and the size of the tree (Size of the Tree) are also indicated. Also a decision tree created in the Test-2 results and a decision tree is formed in the Test-1 result are the same. This is also shows that the size of the training data don’t
changing characteristics that impact on estimates but the size of the data affects education level of learning algorithm. The results of estimation procedures of SMO algorithm, the weight vector which will be made of the best estimate process is determined by creating a weighting coefficient for each feature. In Figure 4, SMO algorithm weights as a result of the features that generate Test-1 operations are shown.

Classification for classes: ckd, notckd

Binary SMO

Machine learning: showing attribute weights, not support vectors.

- 0.068 * (normalized) age
- 0.0301 * (normalized) bp
- 1 * (normalized) sg=1.010
- 1 * (normalized) sg=1.015
- 0.9411 * (normalized) sg=1.020
- 1.0589 * (normalized) sg=1.025
- 1.1339 * (normalized) al=0
- 0.5191 * (normalized) al=1
- 0.1061 * (normalized) al=2
- 0 * (normalized) al=3
- 0.5098 * (normalized) su=0
- 0.5025 * (normalized) su=2
- 0.4178 * (normalized) rbc
- 0.1061 * (normalized) poc
- 0 * (normalized) ba
- 0.3249 * (normalized) bcr
- 0.6150 * (normalized) bu
- 0.3926 * (normalized) sc
- 0.1445 * (normalized) sod
- 0.0331 * (normalized) pot
- 0.9869 * (normalized) hemo
- 0.0102 * (normalized) pcv
- 0.0276 * (normalized) wbc
- 0.5053 * (normalized) rbc
- 1 * (normalized) htn
- 1.6143 * (normalized) dm
- 0 * (normalized) cad
- 1.4178 * (normalized) appt
- 1 * (normalized) pe
- 0 * (normalized) one
- 6.5142

FIGURE IV. The SMO Algorithm Weight Vector Form of Test-1 Results

In Figure 4, when the weight of the vector by the result of SMO algorithm examined, it has been observed that some features of the weight is calculated as zero. As it is understood from this result, zero weight values properties do not have an effect on the process of the estimating. The characteristics which its coefficient equal zero has no effect on the estimation process. Because all the features form the weight vector with coefficient values, the features having nonzero coefficients are not possible to sort by the coefficient values.

Weight vectors generated as a Test 1 and Test-2 results of SMO algorithm are the same. This is also showed that effective to change properties on the estimated size of the data affect the level of training algorithm. It has been show that the data size cannot change the properties that effective on the estimates but it showed that the algorithm affect the level of education.

Confusion Matrix of J48 and SMO algorithms formed in Test-1 and Test-2 results are shown in Figure 5.

FIGURE V. The Confusion Matrix of J48 and SMO algorithms

As it is seen from the confusion matrix of algorithms; J48 classification algorithm was not making a mistake in Test-1 and the error is 0%. However, 21 patients were classified as non-patients and 9 non-patients were also classified as patient and the error is 8.33% in Test-2. SMO algorithm were classified 4 patients as non-patients in the Test-1 results and error is 2.94%. And 9 patients were classified as non-patients and 5 non-patients were also classified as patient and the error is 3.88% in Test-2.

V. CONCLUSIONS

Chronic Kidney Disease a longer disease that prevents the normal duties of the kidneys and causing any damage the kidneys. The early detection of this disease is very important in terms of health and treatment costs. In this study, using the data of consisting the 250 chronic kidney disease patients and 150 non-patient people data set, classification of patients was estimated by the help of support vector machine and decision tree algorithm. Training and testing process of algorithms were measured by creating two different sets of data. As a result of different data size and prediction operations performed with different algorithms, it has been shown that the size of the training data algorithms to be largely effective for the estimating.

In the classification stage, decision tree has been more successful than the support vector machine recognition of 97% to 100% recognition. Forecasting and phase accuracy, it has...
been observed that made an accurate estimate of 100% rate with the decision tree in the Test-1 data set and an accurate estimate of 91.67% rate in the Test-2 data set. Also it has been observed that made an accurate estimate of 97.06% rate with the SVM in the Test-1 data set and an accurate estimate of 96.12% rate in the Test-2 data set.

With the data used in this study showed that the decision tree gives better results than the support vector machine for the early diagnosis of chronic kidney disease. High rate results was obtained in terms of performance as compared with results in the literature

REFERENCES


Abstract—In this study, it is aimed to reduce the variability of parameters in the liquid level system controlled by PID controller for a laboratory scale device. An integrated methodology consisting of experimental design and feedback PID (proportional-integral-derivative) controller was proposed to optimize and control the deviation from the average value in the offset value, variability in the offset value and the time to reach the set value in this liquid level system. The optimal valve opening levels that minimizes the average of the offset value (µ), variance (s2) and the first time to reach the set value (t) were determined as 40%, 5%, 50% and 80%, respectively, using TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution)-based Taguchi method by Minitab®. A quite successful control was established in the verification test which performed with specified levels of optimal valve opening. Recovery rates in the control performance before and after optimizing the parameter were calculated as 9.53% in the deviation from the average value in the offset values, 29.37% in the variability in the offset value and 11.27% in the time to reach the set value. MATLAB/Simulink was used to simulate the liquid level system.

Keywords—Laboratory Scale Liquid Level System, TOPSIS based Taguchi Parameter Design, PID Controller and Performance Improvement

I. INTRODUCTION

Liquid level loops are frequently encountered in many process industries such as waste water management systems and petrochemical processes [1] – [4]. Especially in the petroleum industry, liquid level is a crucial parameter for production at oil wells [5]. In recent years, many researchers studied on controlling of liquid level systems [6]. Sbarbaro and Ortega (2007) proposed a new approach to control the multi-tanks systems [7]; Almutairi et al. (2007) proposed several sliding mode control diagrams for the coupled tanks [8]; Lee and Shin (2009) applied constrained control to liquid level system using conventional PI (proportional-integral) controller [1]. Zhang et al. (2011) modelled and controlled the liquid level in a coke fractionation tower using non-linear based predictive control [9]. Noel and Pandian (2014) proposed an integrated methodology including artificial neural network based reinforcement learning approach for controlling of a nonlinear liquid level system [10]. Sadeghi et al. (2014) designed a method based on parallel distributed compensation via fuzzy Takagi-Sugeno model for a liquid level system [11]. Singh et al. (2014) reduced flow rate fluctuation for tank in series with PI controller [12]. Zhang et al. (2014) offered PI controller based on predictive functional control for liquid level in a coke fractionation tower [9], [13]. In the literature, many studies contain process optimization and control applications have proposed for various industrial areas. Some of these studies are as follows; Tao et al. (2014) applied predictive control based PID design with genetic algorithm for chamber pressure in coke furnace [13]; Zhang et al performed model predictive control optimization based PID control for temperature in an industrial surfactant reactor [14]; Zhang and Yang (2014) developed an incremental- PID-controlled particle swarm optimization algorithm for EGG-data-based estimation of operator functional state [15]; Sahu et al. (2015) proposed teaching-learning based optimization algorithm based fuzzy-PID controller for automatic generation control of multi-area power system [16]; Gizi et al. (2015) formulated an integrated approach programmable logic controller-fuzzy PID methodology to determine optimal PID parameter in automatic voltage regulator [17].

Many difficulties are experienced in liquid level control systems owing to the variability in the parameters and flow resistance [3]. Parameter variations that should be controlled can be originated from pumps, agitators or the natural causes [3]. In this study, it is aimed to reduce the variability of parameters in the laboratory scale liquid level system controlled by PID controller. Purpose of reduction of parameters’ variability and noise effect with the methodology including multi-criteria decision making (MCDM) based Design of Experiment (DoE) for finding optimal valve opening levels and process control performance improvement. Moreover, the improvement rate was also specified by finding valves’ opening levels to optimize the process control performance. Giving a positive and negative effect on the system, system performance was evaluated after the parameter optimization. Matlab/Simulink® was used to simulate the laboratory scale liquid level system (LSLLS).
II. Proposed Materials & Methodology

A. Materials

Liquid level control techniques can be applied experimentally by LSLLS building up standard industrial material (Figure 1). It is possible to observe the control techniques used in the industry. P, PI and PID control methods can be examined experimentally with LSLLS.

The reaction of the control data can be measured with changing operation conditions. Pressure tracking can be done in four different points via manometer. Liquid level in the plexi tank can be measured by HK Instruments DPT-R8 differential pressure sensor. Accuracy of DPT is ±1.5% or ±6 Pa under 250 Pa. Control data can be recorded by the Pangu KT104 digital data recorder. It can record and show process data graphically and visually. Width of the cylindrical liquid tank of LSLLS is 75 cm and height of the tank is 200 cm. Experimental set has a pneumatic proportional valve consist of Young Tech Instruments YT100 electrical junction box, positioner, PVD T-PA40 pneumatic actuator and an 1.0 inch inner diameter ball valve.

Valve no. 1 breaks the water come from the water pump, Valve no. 2 is the by-pass valve connected to pneumatic proportional valve, Valve no. 3 is located at the plexi tank water inlet and Valve no. 4, drain valve, is located at the plexi tank water outlet. The block diagram of the LSLLS was given in Figure 2.

B. Proposed Methodology

Proposed methodology contains two stages including parameter optimization and control. In first stage, optimal valve opening levels was determined to minimize the deviation from the average value in the offset value, variability in the offset value and the time to reach the set value in this liquid level system using TOPSIS based Taguchi methodology. In second stage, process control performance of the system was monitored via optimum valve opening; dynamic behavior of LSLLS with positive and negative step change was examined, closed-loop block diagram was established by Matlab/Simulink® and process control performance improvement rate was calculated between former and optimal valve opening levels. Flow diagram (including 10 flow steps used in the study in process control performance optimization of LSLLS) is given in Figure 3.

C. Determining Performance Criteria for the Success of Process Control

Three performance criteria for the success process control were defined as deviation from the average value in the offset value, variability in the offset value and the time to reach the set value [18]. Target values and weights of performance criteria were given in Table 1.

Offset values is steady-state difference between the set point which is 60 cm with the actual point obtained in liquid level control system. The average of these values were defined as mean of the offset values, the variance of these values were defined as variance of the offset values, respectively. Time to reach the set point was described as the first time to reach 60 cm. 8th, 7th and 4th values were designated to mean of the offset values, the variance of these values and time to reach the set point, respectively. All criteria representing process control performance are required to be minimized.

D. Determining Levels of Performance Criteria

Each globe valve which has ½ inch inner diameter effect on performance criteria has three levels and their description was shown in Table 2. Tank no. 1 filled with city water was used as fluid in the system. Process parameters, valve opening levels, were set before each experiment’s implementation. The system was run for
Several model approaches can be used for process control applications. Theoretical models which are obtained by process physics and chemistry can be used in industry. Development of theoretical models may not be a practical way when model requires process variables and unknown parameters (i.e. physical and chemical properties) including many equations. Development of an empirical model from experimental data directly can be an alternative approach [20].

### III. RESULTS AND DISCUSSION

#### G. Results

In Table 3, columns 2–5 represent the four control factors and their levels. In this study, a Taguchi’s $(3^4)$ orthogonal array was used to implement the experiments and results are given in Table 3 [21]. Findings relevant to the deviation from the average value in the offset value, variability in the offset value and the time to reach the set value in this liquid level system were given in columns 6–8. Table 3 also contains PID tuning parameters such as proportional gain, integral gain, derivative gain which is shown in columns 9-11.

#### H. TOPSIS Based Taguchi Design

In this study a Taguchi orthogonal array $(L_{9\times3})$ was selected to implement the experiments. Signal to noise ratio (S/N) were calculated for the smaller the better type responses and given in columns 2-4. Let $n_i$ be the S/N for the response $j$ of experiment $i$ and let $y_{ijk}$ be the experiment result for the response $j$ of experiment $i$, in the $k^{th}$ replication; $n$ is the total number of replications [19], [22]. The calculation of the S/N ratio can then be determined as [23];

$$n_j = -\log K_C \left( \frac{1}{n} \sum_{k=1}^{n} y_{ijk}^2 \right)$$  (2)
In Table 4, columns 5-7 are shown as decision matrix which is essential step of the TOPSIS method [27]. The positive ideal solution \((S_i^+)_i\) and negative ideal solutions \((S_i^-)_i\) and \(C_i^*\) \((i=1\ldots9)\), are the surrogate responses for the multi-response minimization problem [19].

The average responses by factor levels can be designated using the additive property [19], [24]. Their associated factor effect plots are given in Figure 4 [19]. Since the effect values are smaller-the-better, normalization methods caused the final parameter design of \(A_2B_2C_3D_2\) which is given in Table 5.

### I. Validation of experiment and PID tuning parameters’ calculation

In order to confirm the optimum valve opening levels achieved using the TOPSIS based Taguchi method, an experimental study was implemented to check whether the deviation from the average value in the offset value, variability in the offset value and the time to reach the set value could really be minimized by the proposed optimum valve opening levels. The confirmation study improvement for mean of the offset values, variance of the offset values, valve opening levels. The confirmation study improvement value could really be minimized by the proposed optimum variability in the offset value and the deviation from the average value in the offset value, experimental study was implemented to check whether the achieved using the TOPSIS based Taguchi method, an

In Table 6 demonstrated that proposed results satisfies the expected set point. PID tuning parameters of validation experiments were calculated as 0.57 for proportional gain, 4.54 for integral gain, and 13.64 for derivative gain using well-known statistical model definition techniques.

### J. Development of a Closed-Loop Feedback Block Diagram Using Matlab/Simulink®

Transfer function of a laboratory scale liquid level system can be modelled utilizing orifice and mass balance equation to describe the dynamics of chemical process given in Seborg et. al. [20]. A block diagram representing the laboratory scale liquid level system was obtained by Matlab/Simulink® tool can be seen in Figure 5. PID controller tuning parameters was received as 0.57 for proportional gain, 4.54 for integral gain, and 13.64 for derivative gain. System response against step change can be seen in Figure 6.

### IV. CONCLUSION

Table II

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 (uncoded values)</td>
</tr>
<tr>
<td>X₁</td>
<td>First Valve opening (%)</td>
<td>30</td>
</tr>
<tr>
<td>X₂</td>
<td>Second Valve opening (%)</td>
<td>0*</td>
</tr>
<tr>
<td>X₃</td>
<td>Third Valve opening (%)</td>
<td>30</td>
</tr>
<tr>
<td>X₄</td>
<td>Fourth Valve opening (%)</td>
<td>70</td>
</tr>
</tbody>
</table>

Underlined values are the predicted levels before the parameter optimization*
which is MCDM based experimental design and process control methodology to improve process control performance in a laboratory scale liquid level system. Following the TOPSIS based Taguchi procedure, process control performance of the system was monitored using optimal valve opening levels. The validation experiment illustrated that the difference in process control performance between the optimal valve opening levels and estimated valve opening levels is significant.

Improvement of parameters between valve opening levels and estimated valve opening levels were calculated as follows; mean of the offset values average, 9.53%, variance of the offset values, 29.37% and time to reach the set point, 11.27%. In addition, improvement of parameters between valve opening levels with a positive step change and estimated valve opening levels were calculated as follows; mean of the offset values average, 34.79%, variance of the offset values, 53.57% and time to reach the set point, 68.08%. Furthermore, improvement of parameters between valve opening levels with a positive step change and estimated valve opening levels were calculated as follows; mean of the offset values average, 58.97%, variance of the offset values, 11.22% and time to reach the set point, 21.50%. It can be seen from the results of system behaviour, that they satisfied the expected success process control performance of LSLLS (Figure 7).

### Table IV

| Exp. No | $\mu$ | $s'$ | $t$ | Weighted Normalized Decision Matrix
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$v_{ij1}$</td>
</tr>
<tr>
<td>1</td>
<td>-15,8343</td>
<td>-31,9222</td>
<td>-39,4626</td>
<td>-0.217</td>
</tr>
<tr>
<td>2</td>
<td>-9.6807</td>
<td>-28.9923</td>
<td>-35.7066</td>
<td>-0.133</td>
</tr>
<tr>
<td>3</td>
<td>-9.6999</td>
<td>-30.4288</td>
<td>-42.1442</td>
<td>-0.133</td>
</tr>
<tr>
<td>4</td>
<td>-9.6516</td>
<td>-29.6654</td>
<td>-40.0864</td>
<td>-0.132</td>
</tr>
<tr>
<td>5</td>
<td>-6.3966</td>
<td>-27.3113</td>
<td>-37.3846</td>
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</tr>
<tr>
<td>6</td>
<td>-8.6912</td>
<td>-28.7228</td>
<td>-38.6900</td>
<td>-0.119</td>
</tr>
<tr>
<td>7</td>
<td>-7.9548</td>
<td>-28.8834</td>
<td>-40.5877</td>
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<tr>
<td>8</td>
<td>-9.5153</td>
<td>-29.3007</td>
<td>-39.4626</td>
<td>-0.131</td>
</tr>
<tr>
<td>9</td>
<td>-11.8116</td>
<td>-32.3152</td>
<td>-36.5215</td>
<td>-0.162</td>
</tr>
</tbody>
</table>

### Table V

<table>
<thead>
<tr>
<th>Factors</th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
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</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>0.4424</td>
<td>0.5019</td>
<td>0.4855</td>
<td>0.4787</td>
</tr>
<tr>
<td>Level 2</td>
<td>0.7933</td>
<td>0.7658</td>
<td>0.5747</td>
<td>0.7425</td>
</tr>
<tr>
<td>Level 3</td>
<td>0.6354</td>
<td>0.6034</td>
<td>0.8108</td>
<td>0.6498</td>
</tr>
<tr>
<td>Optimal factor levels</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

*optimum levels were shown in bold font

### Table VI

<table>
<thead>
<tr>
<th>Responses</th>
<th>Description</th>
<th>Estimated mixture levels before Taguchi experiments A, B, C, D</th>
<th>Optimal mixture levels after Taguchi experiments A, B, C, D</th>
<th>Improvement rate (dB)</th>
<th>The percentage of improvement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mean of the offset</td>
<td>2.49884</td>
<td>2.260758</td>
<td>0.238082</td>
<td>9.53</td>
</tr>
<tr>
<td>1</td>
<td>values (cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>variance of the</td>
<td>27.8080</td>
<td>19.63998</td>
<td>8.16802</td>
<td>29.37</td>
</tr>
<tr>
<td>1</td>
<td>offset values (cm²)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>time to reach the</td>
<td>107</td>
<td>95</td>
<td>12</td>
<td>11.27</td>
</tr>
<tr>
<td>1</td>
<td>set point (s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
V. REFERENCES


Comparing the thermal performance of traditional building and reinforced concrete building based on TS 825 (Thermal insulation requirements for buildings)

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Abstract—This study has been composed for the aim of making a comparison of the requirements for heating energy within TS 825, between the houses built with reinforced concrete frame technique which most commonly used in today’s Turkey and the houses built with the traditional building techniques. For this purpose, energy requirements of two storey detached reinforced concrete frame building calculated according to TS 825, separately for with thermal insulation and without thermal insulation. Obtained values, compared with energy requirements according to TS 825 of traditional buildings with mixed structural system used combination masonry and wood frame structure. According to the results of the calculations for the reinforced concrete structure according to the TS 825, the maximum permitted annual heating energy requirement 29.99 kWh/m3. Building with thermal insulation appropriate to the TS 825, annual heating energy needs calculated as Qyear =29.47 kWh/m3. Building without thermal insulation appropriate to the TS 825, the annual heating energy requirement is calculated as Qyear = 91.84 kWh/m3. A building without thermal insulation consumes three times more energy than a house with thermal insulation. The third building with the traditional construction system, annual heating energy needs calculated as Qyear =27.76 kWh/m3. But the annual heating energy requirement is calculated as Qyear =60.77 kWh/m3/ţür. The value obtained by calculation, more than twice the permitted value. When the calculation results of both the traditional building and the reinforced concrete building is compared, the thermal insulation made form of a house has the minimum energy consumption. And it has been determined that the energy consumption value of a traditional building is less than a reinforced concrete building. As a result, modern reinforced concrete structures, if they are not insulated very high level of energy consumed. For this reason, the value of thermal conductivity with new buildings must be appropriate to the region. Appropriate thermal insulation requirements, can be achieved using thermal insulation materials, or as with examples of traditional building, can be achieved using high thermal values building components.

Keywords— TS 825, A reinforced concrete frame construction system, Traditional construction system, Thermal insulation, Energy consume

I. INTRODUCTION

The natural resources of the earth are continuously depleted due to the rapidly increasing World population, developing industries and technology, including the unplanned urbanization, and based on this depletion, many global and local environmental problems occur. For example, the Carbone dioxide level of the atmosphere surrounding the earth (CO2) reached to a 400 ppm (400 in a million) since 1958 in accordance with the measurements carried out on 9th May, 2013. This increase in the CO2 is the most important reason for the global warming and climate variation [1]. It is an obligation for Turkey to decrease the greenhouse gas emissions used in the buildings is an important part of the inventory. The emission increased 3.92% annually in average since 1990. There is an increase of 5.1% as per the data of the year 2010. The most part (16.2 millions) of 20 million tonnes (approximately) increase of Carbone dioxide equivalent is energy based. 2.2 million of the rest is industrial based, while 1.7 million is agricultural. While 9.4 million tons of energy based increase is due to the natural gas and coal used in electric power production, 3.2 million tons of the rest is for transportation, and the 3.4 million tonnes is based on the electric power used for iron & steel, cement industry [2]. One of the main reasons of carbon emission is the usage of fossil based energy resources. The buildings globally have one of the biggest shares in energy usage. The power consumption ratio of housing industry in Turkey is 35% as per the data for the year 2010 [3]. The power consumption in the buildings increased 44% since 2002 to 2010 in Turkey [4]. Fossil fuel based Greenhouse gas emissions used in the buildings is an important part of the inventory. The emission levels are calculated via the energy provided by the fuel. The power consumption level increased to 280 Millions of TJ in 2002, while this amount was 240 million of TJ (Tera joule) in 1990. In terms of greenhouse gas, the carbon dioxide emission level reached to a level of 52.6 million tons in...
2011, while this amount was 23 million tons in 1990 [2]. One of the main reasons for the increase in the power consumption of buildings is based on the socio-economic increase of the users, yet this cannot be prevented through various measures to be taken. The buildings consume the biggest part of the power energy during the utilization stage within the lifecycle [5]. The biggest part of the utilization is based on the heating and cooling matters. The first stage of decreasing the power energy consumption in the utilization process is to design an effective planning in the structure. After this comes the generalization of renewable energy resources in the buildings, producing building elements with low heat conductivity, as well as usage of low-energy household appliances. Producing of low-heat-conductivity building elements can be carried out using structural materials with low heat conductivity, as well as increasing the thickness of structural materials, generating fixed air gap between the building elements or using heat-insulation materials.

The applications & practices for decreasing the power consumption in the buildings are still not being utilized in required levels, even if some of them cause no extra expenditure. In accordance with the housing power consumption survey carried out by Turkish Statistical Institute in 1998, 84% of the existing buildings are single-glazed, and only 16% of them do have the roof insulation. In line with the “Comprehension Survey” data carried out by the Heat, Water, Noise and Fire Insulation Association, only 9% of the consumer utilized the insulation, when the consumers applying insulation on the buildings they’re residing are in question [6]. However, the traditional buildings in our country are designed taking the climate data into consideration, thus integrating the traditional building materials in a manner keeping the heat transmission coefficient low. Therefore, this study was carried out to analyse the traditional buildings within the framework of today’s standards, as well as making a comparison in terms of today’s buildings and power consumption. In this manner, a housing Project designed taking the climate data into consideration was analysed in line with TS 825 both as insulated and uninsulated in terms of power consumption. A traditional building in the central area of Kırklareli was analysed, as well. The obtained results were evaluated and concluded.

When the previous studies are analysed concerning this subject matter, a study which has the most similar perspectives with this article was carried out by Korumaz et al. The power consumption performances of four traditional Gaziantep buildings and three modern Gaziantep buildings were compared in accordance with the TS 825 version 2000 in a study carried out in 2006. The traditional buildings in this study are stone-walled as typical in the regional architecture. Two of the modern buildings are in form of apartment building, while one of them is a detached house (villa), their carrier systems are reinforced concrete framing, with no heat insulation. According to the results obtained in the comparisons carried out, the power consumption performance of traditional buildings is better than the modern buildings in terms of both average heating energy needs, and of annual heat loss ratio [7]. A comparison on thermal conditions was carried out based on the measurement made obtained in a traditional building and a modern building under the same climate conditions in a study carried out by Priya et al. With this study, it can be clearly understood that the traditional buildings are much more comfortable than the modern houses, in India, Tamil Nadu, Nagappatina coastal areas with moist and hot climate [8]. The traditional buildings and modern buildings in Kerala located in the South India in coastal areas were compared through the measurement of such factors as thermal comfort conditions, temperature, humidity, air flow, thus obtaining results through these measurements with a survey, in a study carried out by Dilia et al. With this study, it can be clearly understood that the traditional buildings in Kerala are quite effective in providing a comfortable environment, regardless of the climate conditions [9]. The thermal performances of an experimental solar house, traditional house and a modern house were subjected to a comparison in a study carried out in Cyprus. This comparison was carried out with a software – Energy 10 - applying PC simulation. With this study, it was confirmed that the comfort conditions can be enhanced on a ratio between 10% - 45% with passive solar energy techniques based on the analysis results. When the annual power consumption performances of these three separate buildings were compared, it was confirmed that the power consumption in the experimental solar house (121KWh/m²) was quite lower than the modern house (368 kWh/m²) and the traditional house (243 kWh/m²) [10].

II. TS 825 THERMAL INSULATION REQUIREMENTS FOR BUILDINGS

A study for saving fuel via decreasing the heating loss in the buildings, TS 825 (Thermal insulation requirements in the Buildings) standard was first published by Turkish Standards Institute (TSI) in February 1970. It was given the name being used today during the first revision applied in June 1979, and it was revised for the second time in April 1985. In line with the demands received from the relevant sector, it was re-regulated with a large-scale revision for providing power saving in April 1998. In this revision, the calculation methodology was completely renewed with local and foreign standards [11]. The last revision for this standards was carried out in 22.05.2008, and additionally a modification was applied to this revision on 17.07.2009. The objective of TS 825 standard is to determine the standard calculation methodology and values to be used for limiting the power consumption amounts, increasing the power saving ratio, as well as calculating the power requirements [12]. For a building to be in conformance with the TS 825 standard, the annual heating energy needs of the building as calculated (Q) must be lower than the annual heating energy edge value in the standard. The accuracy of the total heat transfer coefficient (U) as calculated for exterior walls, ceiling, surface or floor (as
the surfaces of building causing the heat loss) must be controlled in accordance with the values as set forth by the standard, taking the specific provisions into consideration. Certain calculations must be carried out for possible condensation in the surfaces of building causing the heat loss, and strict attention should be paid for not causing any condensation, or keeping the condensation level under the evaporation level, in a harmless level.

It must be ensured that the internal surface temperatures are designed in a manner of which value is 3°C (max.) less than the internal environmental temperature value, for not causing mould growth and disrupting the comfort conditions, including not causing any condensation on the exterior surfaces of the building with heat loss [12].

III. CALCULATION OF ANNUAL HEATING ENERGY REQUIREMENTS OF TRADITIONAL BUILDINGS AND MODERN BUILDINGS AS PER TS 825

Two separate buildings were selected to compare the power consumption amounts of traditional and modern buildings in the residential building example. One of these two buildings is a detached house in Kırklareli with a reinforced concrete framing, and the other one is a traditional building structured in the beginning of 20th century in Kırklareli’s central area. In this study, TS 825 Temperature Insulation Calculation Program was used, as designed by Association of Gas & Concrete Manufacturers in Turkey. With this program, various structures and many sections, doors, Windows et al. can be generated with the software which is in full conformance with the acceptance requirements and methods as set forth in TS 825. Using this software; specific heat loss, annual heating energy requirements, condensation schedules and diagrams can be easily prepared, thus generating reports on this matter [13]. In these calculation the internal temperatures of the buildings were deemed to be 19°C, the fuel to be coal, and the ventilation method to be natural. On the following, you can see the analyses made for these buildings within the scope of TS 825 Standard.

A. Analysis of a Modern Reinforced Concrete Building within the Scope of TS 825

The building is located on a 350m² land, as two-storey and detached house. On the ground floor; the living room and hall are located on the facade, while the kitchen, entry, bathroom and stairs are on the rear front. On the upstairs; the bathrooms are located on the facade, while the bathroom and walk-in closet are on the rear entry. The terrace is located on the South front of the structure (Figure 1). The infill walls of the structure with reinforced concrete framing carrier system are made of bricks. The joineries were planned to be heat insulated double-glazed plastic. Various measurements for the structure are listed on the following table (Table 1).

![Figure 1. Ground and second floor plan of reinforced concrete skeleton building](image)

<table>
<thead>
<tr>
<th>Element of Buildings</th>
<th>Traditional</th>
<th>Modern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columns and beams area (m²)</td>
<td>102.42</td>
<td>124.72</td>
</tr>
<tr>
<td>Interior wall area (m²)</td>
<td>247.55</td>
<td>269.98</td>
</tr>
<tr>
<td>Windows area / Wall area</td>
<td>20%</td>
<td>24.94%</td>
</tr>
<tr>
<td>Total window area (m²)</td>
<td>46.38</td>
<td>54.60</td>
</tr>
<tr>
<td>Total wall area (m²)</td>
<td>546.00</td>
<td>240.00</td>
</tr>
<tr>
<td>Total floor area (m²)</td>
<td>240.00</td>
<td>240.00</td>
</tr>
<tr>
<td>Total building volume (m³)</td>
<td>120.42</td>
<td>240.00</td>
</tr>
<tr>
<td>Windows area according to the direction (m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>North</td>
<td>East</td>
</tr>
<tr>
<td>1.80</td>
<td>8.80</td>
<td>10.84</td>
</tr>
</tbody>
</table>

TABLE 1. THE DIMENSIONS OF THE BUILDINGS ELEMENT OF REINFORCED CONCRETE FRAME BUILDING

1) Calculation of the Annual Heating Energy Requirements of the Heat-insulated Building with Reinforced Concrete Framing: The annual heating energy requirement for the building approved by TS 825 is $Q' = 29.99 \text{kWh/m}^3$ (max.). The annual heating energy requirement for the building is $Q_{\text{year}} = 29.47 \text{kWh/m}^3$, as calculated. Total heat loss of the
building is 336.22 W/K. 220.90 W/K of this loss is through transmission, while 115.32 W/K of it is through ventilation. The table indicating the building elements causing the loss through transmission is on the following (Table 2). When the data on the table is analysed, the biggest heat-loss occurs due to the windows. No condensation was observed on the building elements as per TS 825. Additionally, the temperature difference between the internal surface and interior environment is lower than 3°C, which is in conformance with the standard requirements. On certain building elements, condensation, which is lower than evaporation, was detected.

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Area (m²)</th>
<th>Heat loss per square meter (W/m²K)</th>
<th>Total heat loss (W/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced concrete ceiling</td>
<td>84</td>
<td>0.29</td>
<td>19.42</td>
</tr>
<tr>
<td>Columns and bemas</td>
<td>68.22</td>
<td>0.47</td>
<td>32.13</td>
</tr>
<tr>
<td>Filling wall with brick</td>
<td>124.72</td>
<td>0.42</td>
<td>52.76</td>
</tr>
<tr>
<td>Windows</td>
<td>46.38</td>
<td>2</td>
<td>92.76</td>
</tr>
<tr>
<td>Ground floors</td>
<td>84</td>
<td>0.47</td>
<td>19.87</td>
</tr>
<tr>
<td>Exterior Doors</td>
<td>1.98</td>
<td>2</td>
<td>3.96</td>
</tr>
</tbody>
</table>

2) Calculation of Annual Heating Energy Requirements of an Uninsulated Building, with Reinforced Concrete Framing: The measurement was performed on the reinforced concrete framing building with 20 cm horizontal perforated brick infilling walls, and with no heat-insulation material on the building elements. Only on the joineries, heat-insulated double-glazed plastic joinery was applied. The annual heating energy requirement for the building approved by TS 825 is Q’ = 29.99 kWh/m³ (max.). However, the annual heating energy requirement for the building is Qyear = 91.84 kWh/m³, as calculated. The value obtained through the calculation is approximately three times higher than the allowed value. The total heating-loss of the building is 832.98 W/K. 717.66 W/K of this loss is through transmission, while 115.32 W/K of it is through ventilation. The table indicating the building elements causing the loss through transmission is on the following (Table 3). When the data on the table is analysed, the biggest heat-loss occurs due to the reinforced concrete elements (flooring, column, and beam). No condensation was observed on the building elements as per TS 825. However, the temperature difference between the internal surface and interior environment is higher than 3°C, which is not in conformance with the standard requirements. On certain building elements, condensation, which is lower than evaporation, was detected.

Table 2. HEAT LOSS VALUES THROUGH BUILDING ELEMENTS IN REINFORCED CONCRETE BUILDING WITH THERMAL INSULATION

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Area (m²)</th>
<th>Heat loss per square meter (W/m²K)</th>
<th>Total heat loss (W/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced concrete ceiling</td>
<td>84</td>
<td>0.29</td>
<td>19.42</td>
</tr>
<tr>
<td>Columns and bemas</td>
<td>68.22</td>
<td>0.47</td>
<td>32.13</td>
</tr>
<tr>
<td>Filling wall with brick</td>
<td>124.72</td>
<td>0.42</td>
<td>52.76</td>
</tr>
<tr>
<td>Windows</td>
<td>46.38</td>
<td>2</td>
<td>92.76</td>
</tr>
<tr>
<td>Ground floors</td>
<td>84</td>
<td>0.47</td>
<td>19.87</td>
</tr>
<tr>
<td>Exterior Doors</td>
<td>1.98</td>
<td>2</td>
<td>3.96</td>
</tr>
</tbody>
</table>

Table 3. HEAT LOSS VALUES THROUGH BUILDING ELEMENTS IN REINFORCED CONCRETE BUILDING WITH THERMAL UNINSULATION

<table>
<thead>
<tr>
<th>Building Elements</th>
<th>Area (m²)</th>
<th>Heat loss per square meter (W/m²K)</th>
<th>Total heat loss (W/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced concrete ceiling</td>
<td>84</td>
<td>3.349</td>
<td>225.05</td>
</tr>
<tr>
<td>Columns and bemas</td>
<td>68.22</td>
<td>2.965</td>
<td>206.02</td>
</tr>
<tr>
<td>Filling wall with brick</td>
<td>124.72</td>
<td>1.215</td>
<td>152.66</td>
</tr>
<tr>
<td>Windows</td>
<td>46.38</td>
<td>2</td>
<td>92.76</td>
</tr>
<tr>
<td>Ground floors</td>
<td>84</td>
<td>0.886</td>
<td>37.21</td>
</tr>
<tr>
<td>Exterior Doors</td>
<td>1.98</td>
<td>2</td>
<td>3.96</td>
</tr>
</tbody>
</table>

B. Analysis of a Traditional Building as per TS 825
A building, built Kırklareli on 1908, is selected as the Traditional Building example. The carrier system of the building is masonry stone-wall with 65 cms of thickness until the sub-basement level. Above the sub-basement, there is a timber-framed Wall with mudbrick-filling with the thickness of 15-17 cms on average on the facade. This Wall is covered with natural Stones with approximately 10 cm thickness (Figure 2). Other fronts were covered with bricks having thickness of 35 cms approximately however there is still a wooden structure within the brick wall. The mezzanine floor laying’s are structured with wooden beams, and these beams do have wooden laying elements on them. The ceiling is made by nailing plaster board under the wooden beams. Fibered lime plaster was applied between the partition joints.

![Image 1: Wood frame Wall with stone coated](image1)

Figure 2a. Wood frame Wall with stone coated

![Image 2: Stone walls and masonry wall combination](image2)

Figure 2b. Stone walls and masonry wall combination

![Image 3: Sections of the wood frame walls and masonry walls in traditional buildings](image3)

Figure 2. sections of the wood frame walls and masonry walls in traditional buildings
The building is designed as per internal-hall planning type. The entrance of the building is directly connected to the Street, thus having a niche with 5-6 steps of a stair. The ground floor has 4 bedrooms and a cellar, while the upper floor has 3 bedrooms and a living room. The corners of each of the bedrooms located near the column has a window (Figure 3).

The annual heating energy requirement for the building approved by TS 825 is $Q' = 27.78 \text{ kWh/m}^3$ (max.). However, the annual heating energy requirement for the building is $Q_{\text{year}} = 60.77 \text{ kWh/m}^3$, as calculated. The value obtained through the calculation is approximately two times higher than the allowed value. The total heating-loss of the building is $974.02 \text{ W/K}$ of this loss is through transmission, while $135.91 \text{ W/K}$ of it is through ventilation. The table indicating the building elements causing the loss through transmission is on the following (Table 7). When the data on the table is analysed, the biggest heat-loss occurs due to the reinforced concrete elements (flooring, column, and beam).

No condensation was observed on the building elements as per TS 825. However, the temperature difference between the internal surface and interior environment is higher than 3°C, which is not in conformance with the standard requirements. On certain building elements, condensation, which is lower than evaporation, was detected.

<table>
<thead>
<tr>
<th>Total area (m²)</th>
<th>Ground area (m²)</th>
<th>Floors</th>
<th>Building volume (m³)</th>
<th>Total wall area (m²)</th>
<th>Basement volume (m³)</th>
<th>Ground floor volume (m³)</th>
<th>First floor volume (m³)</th>
<th>Total window area (m²)</th>
<th>Window area – wall area ratio</th>
<th>Exterior Door area (m²)</th>
<th>Window and Dado area – wall area ratio</th>
<th>Windows area according to the direction (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>339.00</td>
<td>113.00</td>
<td>3</td>
<td>919.89</td>
<td>284.39</td>
<td>161.660</td>
<td>395.500</td>
<td>362.730</td>
<td>63.78</td>
<td>% 17</td>
<td>8.66</td>
<td>% 20</td>
<td>South: 22.56, North: 7.94, East: 19.05, West: 14.23</td>
</tr>
</tbody>
</table>

Figure 3. Floor plans of the traditional houses

Figure 4. Pictures showing the front and side facade of the traditional houses
TABLE 5. HEAT LOSS VALUES THROUGH BUILDING ELEMENTS IN TRADITIONAL BUILDING

<table>
<thead>
<tr>
<th>Building elements</th>
<th>Area (m²)</th>
<th>Heat loss per square meter (W/m²K)</th>
<th>Total heat loss (W/K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood frame wall with stone coated</td>
<td>52.52</td>
<td>1,314</td>
<td>71.43</td>
</tr>
<tr>
<td>Brick wall</td>
<td>231.87</td>
<td>1,012</td>
<td>234.65</td>
</tr>
<tr>
<td>Stone wall</td>
<td>23.57</td>
<td>0.934</td>
<td>12.43</td>
</tr>
<tr>
<td>Baghdadi ceiling</td>
<td>113</td>
<td>1,693</td>
<td>85.79</td>
</tr>
<tr>
<td>Wood floor</td>
<td>113</td>
<td>1,752</td>
<td>39.95</td>
</tr>
<tr>
<td>Windows</td>
<td>63.78</td>
<td>4.8</td>
<td>363.55</td>
</tr>
<tr>
<td>Exterior doors</td>
<td>8.66</td>
<td>3.5</td>
<td>30.31</td>
</tr>
</tbody>
</table>

IV. EVALUATION

As per the results obtained from the calculations made, the annual heating energy requirement for the building approved by TS 825 is $Q' =29.99$ kWh/m³ (max.). The annual heating energy requirement for the building after the TS 825 standard requirements are applied, is $Q' =29.47$ kWh/m³. The annual heating energy requirement for the building is calculated as $Q_{\text{year}} =91.84$ kWh/m³ without the heat-insulation. The building without heat-insulation needs three-time higher heating energy than the heat-insulated building. The annual heating energy requirement for the traditional building plan as approved by TS 825 is $Q' =27.78$ kWh/m³ (max.). The annual heating energy requirement for the traditional building, is $Q_{\text{year}} =60.77$ kWh/m³. The calculated value is two times higher than the allowed-value. When the calculation results of traditional building and reinforced concrete building are compared, the energy consumption of the reinforced concrete building – with heat-insulation – is on the lowest level (Table 6). It is also confirmed that the energy consumption value of the traditional building is lower than the reinforced concrete building without heat-insulation. Therefore, it can be clearly concluded that the building elements used in the traditional buildings are quite effective for thermal characteristics.

TABLE 6. THE ANNUAL ENERGY CONSUMPTION VALUES OF REINFORCED CONCRETE BUILDING AND TRADITIONAL BUILDING

<table>
<thead>
<tr>
<th></th>
<th>Annual heating energy needs of reinforced concrete building, (kWh/m³)</th>
<th>Annual heating energy needs of traditional building, (kWh/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted value by TS 825</td>
<td>29.99</td>
<td>27.78</td>
</tr>
<tr>
<td>Insulated building</td>
<td>29.47</td>
<td></td>
</tr>
<tr>
<td>Uninsulated building</td>
<td>91.84</td>
<td>60.77</td>
</tr>
</tbody>
</table>

When a comparison is made as building elements based, the highest amount of heat loss is caused by the Windows in a reinforced concrete building with heat insulation. For reaching to the peak level concerning the energy consumption performance of this building, high-performance joineries and windows should be used. Additionally, for the reinforced concrete building without heat insulation, the highest heat-loss is caused by the laying’s and reinforced concrete building elements. On the traditional buildings, the joinery area on the exterior front is enlarged, since the windows are designed as French Windows. Thermal conductivity of the joineries designed with wooden materials and as single-glazed is relatively higher. Therefore, a significant part of the energy - loss in the buildings is caused by the joineries. The traditional buildings were built in accordance with the day’s technology, building elements, climate conditions and user requirements. Additionally, the usage conditions of traditional buildings are quite different that today’s conditions. For example, there are separate bedrooms in traditional buildings for both summer and winter, these are two separate rooms used in both summer and winter, thus changing the function of the room, as well. In traditional Turkish buildings, this room is used as a living room, for sleeping, eating, like a kitchen or bedroom. Today, these activities are performed in separate rooms in the modern buildings like bedroom, living room, kitchen, et al. In other words, it can be clearly said that an “economy” is applied on the traditional building rooms. All the calculations made are for achieving the complete heating of traditional building. Therefore, the principle of “heating only the room in use” (in traditional buildings) is ignored in this study. In traditional buildings, the windows are generally located on the South fronts. In this way, passive solar energy is can be obtained, besides the heat-storage features of such building elements as brick, stone and mudbrick are comparatively better than the horizontal perforated bricks, gas-concrete building elements used in today’s modern buildings. Since the building elements with heat-storage characteristics get heated and cold slowly, the comfort conditions for the building can be sustained for a longer period of time, without the need of additional energy consumption.
V. CONCLUSION

Reinforced concrete is the most preferred building element in today’s carrier systems used in Turkey. Buildings with reinforced concrete system do not indicate any difference as per the region it is located, thus not being reflected any climate characteristics in its structure. The reinforced concrete building elements, by itself, cannot meet the comfort requirements, neither. In this study, it is confirmed that the reinforced concrete buildings without heat-insulation cause higher heating energy losses. After using heat-insulation materials, heating energy consumption is dramatically decreased. The energy consumption of traditional buildings structured with such building elements as stone, mudbrick and wood, is comparatively higher than the reinforced concrete building with heat insulation. The weakest link in the traditional buildings in terms of protection of energy is detected to be the windows. The ratio of energy loss caused by the windows and door joineries is 1/3 within the whole energy loss. This ratio can be dramatically decreased by reducing the size of joinery area, as well as using heat-insulated windows. Heat transmission values of the Wall elements (U value) is higher than the value as required by TS 825 for 3rd level areas, yet it is within the acceptable range. Heat transmission values of such horizontal building elements as plasterboard ceiling and wooden floor are comparatively higher than the walls.

As stated on certain traditional building examples, this heat transmission value can be decreased by using such materials as mudbrick mortar fodder. The total performance of the building can get closer to the heat-insulated building, by this way. The traditional buildings have been designed with traditional building elements taking the climate conditions into consideration. On the other hand, the modern buildings can be designed with modern building elements and advanced building Technologies by means of PC technology, in a more efficient and very cost effective manner. In addition to these features, modern designers should not ignore benefitting from the traditional building having the experiences of the past.

REFERENCES

A MATLAB SIMULATION OF POSITIONING OF POLITICAL PARTIES IN THE OPINION SPACE

Abstract—Catch-all parties appealing to wider groups of citizens position themselves near the center of the opinion space representing the median voter’s opinion, but small parties tend to represent border-line, extreme opinions. In this paper, we verify these observations with a simple simulation searching for optimal positions of political parties in a multi-dimensional circularly-uniform opinion space that will maximize the average level of representation throughout the space. The results indicate that optimal positions are seemingly unique in cases two or more parties compete in a perfectly proportional voting system. We argue that more involved forms of such simulations may be used to foresee the consequences of policy shifts of parties, changes in the perceptions, or any other deviations from the highly idealized situation analyzed here.

Keywords—Simulation, Matlab, Political parties, Spatial theory, Electoral competition

I. INTRODUCTION

A. A Literature Review on the Spatial Theory

In a brief historical review of the use of mathematical models in political science, Johnson [1] describes the beginnings of the spatial model, which implied that the position of the median voter in a one-dimensional opinion space was the equilibrium point for the competing political parties. However, as noted in that same review, this view could not be extended to higher dimensions. Ortin [2] notes such a convergence is the expected result when two political parties compete in a one-dimensional opinion space, with full knowledge of voters’ preferences, but when the information about those preferences is uncertain, the parties distinguish themselves with their ideologies, meaning the results are also uncertain. However, that argument is probably only valid for majoritarian electoral competitions where the winner takes all. As noted by Dow [3], taking neutral positions near the center is the typical behavior of parties competing in majoritarian systems, whereas proportional representation may also reward small parties shifting to off-center positions.

Actual election results indicating deviations from the median voter theorem are also discussed by Schofield [4]. In an effort to account for those deviations, he attempts to construct a model extending a previous one by allowing for valence, i.e. the biased opinions of voters about the parties or the candidates. He presents highly rigorous mathematical theorems, but his conclusions are limited to some qualitative remarks about the positions taken by parties according to their voter-attributed valence values.

Degan and Merlo [5] also note the spatial theory implies that voters vote ideologically; in other words, they decide according to how close the parties or candidates stand in the multiple dimensions of the opinion space with respect to the voters. Busch [6] is another author who dwells on the implication that voters decide after comparing their political stances with those of the parties, with the added note that the accuracy of the comparisons is limited by how well the voters observe the changes in party policies, for example, along the left-right ideology dimension. Budge and McDonald [7] also point to the left-right ideological scale as a primary factor in voters’ decisions in different democratic countries, but analyze how the voting affects the election outcomes and the subsequent policy changes of the parties.

The perceived positions on a left-right scale, however, cannot be seen as the only determinants of voters’ decisions. Grittersova et al. [8] argue that major, or “mainstream parties,” tend to be evaluated according to their left-right stances, but smaller, radical parties (i.e. “niche parties”) rely on the support they build on issues along other dimensions, such as the economic stances they take, especially when “incumbents are forced to adopt austerity policies.” The party size, as measured by the average number of seats that it usually obtains in the legislative body, appears as another – albeit moderately influential- factor in Dahlberg’s study [9]. The author notes that it will be harder for voters to accurately determine the ideological stances of major parties appealing to larger opinion ranges, leading to the conclusion that catch-all parties take mostly neutral stances along basic opinion dimensions, without alienating many voters with more specific ideological stances.

B. The Reasoning Behind the Presented Model

From this brief literature review, we can draw a conclusion that voters cast their votes according to the perceived distances between their own and political parties’ positions in a multidimensional opinion space. As mentioned in the introduction of the paper by Thurner [10], we can attribute a “utility function” to a voter, specifically, “a decreasing function of the Euclidean distance from the voter’s ideal point.” The distance in the opinion space between the voter and a political party will determine the value of that utility function, namely, how well that specific party represents that particular voter.

With such a model in hand, one can search for equilibrium points at which parties will settle for maximizing their vote shares or probabilities of winning, as analysed by Patty [11], but studies on such models usually seek for Nash equilibria, which do not seem to exist outside fairly limited conditions, such as when three or more candidates compete [12]. It is natural to presume that candidates seeking maximum possible voters will try to take shortcuts by shifting towards the most neutral points in the opinion space, but so can the others, meaning that far-sighted candidates may be better off by preserving their political stances [13], rather than losing their appeal to voters for whom they had higher utilities.
restrictive spatial models have been proposed, as reviewed by Williams [14], to build upon the Downsian model of vote-maximizing electoral competition. Rather than trying to limit the complicated interplay between the policy shifts of parties, we feel the need to build a simpler, more basic model which places the emphasis on the voters rather than the parties, and search for the optimum positions which would maximize not the vote shares of parties, but the combined utility of the parties, i.e. the average level of representation as perceived by the voters.

II. PRESENTATION OF THE MODEL

C. Underlying Assumptions

With seemingly no similar work in the political literature, a new model like the one presented here must be constructed on a fairly basic foundation based on rather simplifying assumptions:

1) It is clear that only in a proportional voting system do political parties value their level of appeal to voters, rather than the actual number of votes they hope to gain in an election. Only then can every party hope to partake in a ruling coalition, if no single party is the winner. Consequently, we start with the assumption that a perfectly proportional representation system with no thresholds is in effect.

2) The opinion space on which parties compete must have a certain geometrical shape and voters must be distributed over that space according to a certain density function. As a starting point, we assume a circularly shaped opinion space in a two-dimensional space over which voters distributed according to a uniform density function whose equation is given below.

\[ C(x, y) = \begin{cases} 1, & x^2 + y^2 \leq 1 \\ 0, & x^2 + y^2 > 1 \end{cases} \]

This assumption will lead to a fairly simple sandbox (well, “sand-dish”) model, but that will be sufficient to draw basic conclusions about the equilibrium points.

3) We assume that voters and political parties perfectly know where they each stand in the opinion space. This is probably the most unrealistic assumption, but once we present the most basic form of this model, more realistic forms can be constructed by working perceptual imperfections and biases into the model in later studies with other collaborators.

4) For the utility function for a political party over the circularly uniform opinion space, we employ a type of Gaussian function which peaks at unit value at the exact position of the party on the opinion space, but does not extend outside the uniformly circular opinion space:

\[ F_i(x, y) = \exp \left( -\frac{4 \ln(2) \left[ (x - x_i)^2 + (y - y_i)^2 \right]}{w^2} \right) \times C(x, y) \]

We assume this function gives the utility of party with the index \(i\) located at the \((x_i, y_i)\) position as perceived by the voter located at the position \((x, y)\). As a measure of the

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We assume this function gives the utility of party with the index \(i\) located at the \((x_i, y_i)\) position as perceived by the voter located at the position \((x, y)\). As a measure of the perceived range of opinions the party appeals to, we propose the parameter \(w\), which, in fact, determines the full-with-at-half-maximum of this Gaussian function.

5) To model a competition between two or more parties over the uniformly circular opinion space, we assume that a voter’s choice will be for the party whose utility function is the greatest at the voter’s position. For example, if \(n\) parties are competing, the combined utility function of the parties over the uniformly circular opinion space can be expressed as follows:

\[ P_i(x, y) = \max\{F_1(x, y), F_2(x, y), \ldots, F_n(x, y)\} \times C(x, y) \]

D. Simulations

The uniformly circular opinion space and the utility functions were evaluated numerically, on a 201x201 mesh grid.
of the Cartesian coordinate system extending from -1 to +1 along both dimensions.\(^1\)

In order to simulate the policy changes of the parties towards the equilibrium positions where the best average level of representation is achieved, random initial locations were selected for the party utility function centers and the optimal locations were obtained by implementing the built-in optimization function available in Matlab. These simulations were repeated 50 times for each combination of FWHM values of party utility functions in two or three party competitions. FWHM values, which represented the extents of voter bases of the parties ranged from -1.0 to 1.0 in dimensionless units also employed to determine the extent of the opinion space.

### III. Results

The most noticeable was that, in all trials for every combination of FWHM values, the final locations provided the same average level of representation, i.e. the same average level for the combined utility function over the circularly uniform opinion space. Of course, this average value actually appears to be the same within the uncertainties of the mesh representation of the opinion space; we derive our confidence from the fact that the percentage error of the mean for the average level of representation was never greater than 0.6%.

The optimal party locations obtained from all the repetitions of the simulations were almost always different in Cartesian coordinates, but they looked the same when normalized according to the position of the major party (the one whose utility function had the largest FWHM value). Therefore, transformation were applied from Cartesian coordinates to polar coordinates where the major party’s angular position was accepted to be 0 in radians.

#### E. Two-Party Results

Optimal party locations averaged over all 50 trials of specific FWHM combinations are presented in the following table.\(^2\)

<table>
<thead>
<tr>
<th>FWHMs</th>
<th>R1</th>
<th>Theta1</th>
<th>R2</th>
<th>Theta2</th>
<th>Avg.Rep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>0.573</td>
<td>2.014</td>
<td>0.495</td>
<td>0.007</td>
</tr>
<tr>
<td>0.1</td>
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<td>0.670</td>
<td>2.739</td>
<td>0.338</td>
<td>0.018</td>
</tr>
<tr>
<td>0.2</td>
<td>0.2</td>
<td>0.498</td>
<td>3.138</td>
<td>0.497</td>
<td>0.029</td>
</tr>
<tr>
<td>0.1</td>
<td>0.4</td>
<td>0.869</td>
<td>2.945</td>
<td>0.154</td>
<td>0.061</td>
</tr>
<tr>
<td>0.2</td>
<td>0.4</td>
<td>0.676</td>
<td>3.136</td>
<td>0.306</td>
<td>0.072</td>
</tr>
<tr>
<td>0.4</td>
<td>0.4</td>
<td>0.490</td>
<td>3.140</td>
<td>0.490</td>
<td>0.115</td>
</tr>
<tr>
<td>0.1</td>
<td>0.5</td>
<td>0.868</td>
<td>3.060</td>
<td>0.103</td>
<td>0.094</td>
</tr>
<tr>
<td>0.2</td>
<td>0.5</td>
<td>0.730</td>
<td>3.138</td>
<td>0.238</td>
<td>0.105</td>
</tr>
<tr>
<td>0.4</td>
<td>0.5</td>
<td>0.556</td>
<td>3.140</td>
<td>0.418</td>
<td>0.146</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>0.485</td>
<td>3.140</td>
<td>0.485</td>
<td>0.176</td>
</tr>
<tr>
<td>0.1</td>
<td>0.8</td>
<td>1.034</td>
<td>2.510</td>
<td>0.017</td>
<td>0.230</td>
</tr>
<tr>
<td>0.2</td>
<td>0.8</td>
<td>0.900</td>
<td>2.871</td>
<td>0.075</td>
<td>0.239</td>
</tr>
<tr>
<td>0.4</td>
<td>0.8</td>
<td>0.701</td>
<td>3.140</td>
<td>0.231</td>
<td>0.272</td>
</tr>
<tr>
<td>0.5</td>
<td>0.8</td>
<td>0.682</td>
<td>3.015</td>
<td>0.286</td>
<td>0.291</td>
</tr>
<tr>
<td>0.8</td>
<td>0.8</td>
<td>0.468</td>
<td>3.141</td>
<td>0.468</td>
<td>0.380</td>
</tr>
<tr>
<td>0.1</td>
<td>0.9</td>
<td>1.000</td>
<td>2.606</td>
<td>0.012</td>
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</tr>
<tr>
<td>0.2</td>
<td>0.9</td>
<td>0.926</td>
<td>2.814</td>
<td>0.051</td>
<td>0.292</td>
</tr>
<tr>
<td>0.4</td>
<td>0.9</td>
<td>0.760</td>
<td>3.078</td>
<td>0.176</td>
<td>0.319</td>
</tr>
<tr>
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<td>0.680</td>
<td>3.141</td>
<td>0.243</td>
<td>0.339</td>
</tr>
<tr>
<td>0.8</td>
<td>0.9</td>
<td>0.516</td>
<td>3.141</td>
<td>0.413</td>
<td>0.413</td>
</tr>
<tr>
<td>0.9</td>
<td>0.9</td>
<td>0.463</td>
<td>3.141</td>
<td>0.463</td>
<td>0.442</td>
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<tr>
<td>0.1</td>
<td>1.0</td>
<td>1.040</td>
<td>2.305</td>
<td>0.008</td>
<td>0.340</td>
</tr>
<tr>
<td>0.2</td>
<td>1.0</td>
<td>0.964</td>
<td>2.599</td>
<td>0.034</td>
<td>0.346</td>
</tr>
<tr>
<td>0.4</td>
<td>1.0</td>
<td>0.764</td>
<td>3.141</td>
<td>0.139</td>
<td>0.370</td>
</tr>
<tr>
<td>0.5</td>
<td>1.0</td>
<td>0.751</td>
<td>3.015</td>
<td>0.187</td>
<td>0.384</td>
</tr>
<tr>
<td>0.8</td>
<td>1.0</td>
<td>0.561</td>
<td>3.141</td>
<td>0.359</td>
<td>0.448</td>
</tr>
<tr>
<td>0.9</td>
<td>1.0</td>
<td>0.509</td>
<td>3.141</td>
<td>0.410</td>
<td>0.473</td>
</tr>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>0.485</td>
<td>3.141</td>
<td>0.458</td>
<td>0.499</td>
</tr>
</tbody>
</table>

Uncertainties of the locations are noticeable in cases the FWHM ratio of the minor to major party is too small, implying that niche parties with extremely small voter bases play little roles in optimizing the average level of representation throughout the opinion space. In such cases, the niche party is also found to be located at the very edge (even beyond) of the opinion space, leaving the major party comfortably fixed at the neutral center.

This behavior is apparent in other FWHM combinations; the major party is closer to the center when the minor party has a smaller base, but shift away from the center to balance the voter base of the minor party. Judging from the angular differences of the locations, parties are expectedly located at the opposite

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\(^1\) The above figures were obtained by plotting the sample functions on a smaller mesh grid of 41x41 for a simpler visualization.

\(^2\) Percentage errors of the mean are given in parentheses if they are equal to greater than 0.1%.
ends of a line passing through the neutral center of the opinion space. This result implies that the two parties must have taken opposite stances in both dimensions of the opinion space in order to maximize the average level of representation as perceived by the voters.

Fig. 3 The relative placements of the political parties with respect to ratios of their voter bases.

Fig. 2 shows the relationship between the ratios the optimal radial locations of the major party to minor party and the FWHM ratio, i.e. the ratio of the extents of parties’ voter bases. It is noted that the locations of the parties with identical voter bases mirror each other, and the larger the voter base of the major party, the close it is to the neutral center.

F. Three-Party Results

Table II shows only a fraction of the results, namely, the optimal locations for parties with identical voter bases. Again, judging from the percentage errors of the means, all simulations for the same FWHM combinations seem to arrive at the same average level of representation. Optimal locations providing this average representation value may possibly be unique, because for these combinations of identical FWHM values, radial and angular locations are similar, but we can make no assertions without implementing a more reliable optimization routine over an opinion space represented by a larger mesh size.

IV. DISCUSSION

This study aimed at determining the optimal positions for the parties in a circularly uniform opinion space that would maximize the average level of the voters, if a perfectly proportional representation system is in effect. The results for the simulations performed for the two-party competitions show that there are such positions and they appear to be unique, when normalized to the location of the major party. The results for the three-party competitions also suggest that unique optimal positions exist, but more elaborate studies are needed to ascertain that.

The results verify the common-sense observations about the political stances taken by catch-call parties with large voter bases and niche parties with small voter bases. Comparisons of the normalized locations show that catch-all parties can afford to take neutral stances without losing appeal to a wide spectrum of opinions, but niche parties or ones with smaller bases realize their vote potentials only by taking more extreme positions on one or both dimensions of the opinion space, so that they can appeal to extremist voters who would not subscribe to neutral views.

However, the results for the three-party competitions tell a different story. Judging from the results presented in Table II, one may conclude that when the competing parties have similarly wide voter bases, they will differentiate themselves in one or both opinion dimensions; the larger the voter base, the more distance they will shift from the neutral center.

It must be remembered that all these conclusions are based on the overly-simplifying assumption that parties and voters all know each other’s exact positions over an idealized representation of the opinion space. This naïve assertion probably makes the conclusions dismissible, but a substantial potential exists for further studies based on more elaborate simulations involving more realistic assumptions.

The literature about the mathematical models of the voting systems and electoral competitions abound with studies which focus on finding Nash equilibria for the positions taken by political competitors; there seems to be no prior study discussing the existence of the equilibrium that would be optimum in terms of voters’ overall satisfaction with the level of representation they perceive. This is the primary reason why the literature review presented in this paper is rather brief.

Prior studies also focus more on electoral competitions of two parties in majoritarian voting systems, probably because they are in effect in certain countries dominating the world politics. The classical median-voter theorem still has validity over such competitions; the competitor will focus on amassing votes at the expense of each other, resulting in undifferentiated political stances near or at the neutral center. This study has taken a different path derived from the hypothesis that parties competing in a perfectly proportional voting system can afford to focus on maximizing the overall satisfaction over their traditional voter bases, instead of greedily seeking for more votes by trying to appeal to voters outside that base. The simulations were performed to determine whether all competing parties starting from randomly selected positions would always arrive at the same final positions, and the results strongly suggest that this is the case. When normalized according to the location of one party, the set of final positions appear to be unique for each distinct combinations of voter base sizes. They are also optimal in the sense that they maximize the average value of the combined utility function of the parties.

These optimal locations may seem to be of little use, because of the highly idealized nature of the model, but the real aim of this presentation is to establish ground for more detailed studies with more collaborators from different disciplines, preferably with political scientists taking the lead. The models constructed in those studies will not only serve as educational demonstrations tools, but they will also help analyze the
probable effects of the policy shifts of the parties in more accurate models of actual electoral competitions.

TABLE III
Optimal Locations for Three-Party Competitions

<table>
<thead>
<tr>
<th>FWHM1</th>
<th>FWHM2</th>
<th>FWHM3</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>Theta1</th>
<th>Theta2</th>
<th>Avg. Rep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.569(3.5%)</td>
<td>0.566(3.4%)</td>
<td>0.545(4.6%)</td>
<td>-1.795(5.2%)</td>
<td>1.847(4.6%)</td>
<td>0.011(0.0%)</td>
</tr>
<tr>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.540(0.4%)</td>
<td>0.540(0.3%)</td>
<td>0.529(1.6%)</td>
<td>-2.096(0.1%)</td>
<td>2.113(0.7%)</td>
<td>0.043(0.0%)</td>
</tr>
<tr>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.541(1.1%)</td>
<td>0.540(0.0%)</td>
<td>0.540(0.0%)</td>
<td>-2.088(0.3%)</td>
<td>2.094(0.1%)</td>
<td>0.097(0.0%)</td>
</tr>
<tr>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.543(0.0%)</td>
<td>0.543(0.0%)</td>
<td>0.543(0.0%)</td>
<td>-2.094(0.0%)</td>
<td>2.095(0.0%)</td>
<td>0.171(0.0%)</td>
</tr>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.545(0.0%)</td>
<td>0.545(0.0%)</td>
<td>0.545(0.0%)</td>
<td>-2.094(0.0%)</td>
<td>2.095(0.0%)</td>
<td>0.258(0.0%)</td>
</tr>
<tr>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
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<td>0.546(0.0%)</td>
<td>0.546(0.0%)</td>
<td>-2.094(0.0%)</td>
<td>2.094(0.0%)</td>
<td>0.347(0.0%)</td>
</tr>
<tr>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.547(0.0%)</td>
<td>0.547(0.0%)</td>
<td>0.547(0.0%)</td>
<td>-2.094(0.0%)</td>
<td>2.095(0.0%)</td>
<td>0.430(0.0%)</td>
</tr>
<tr>
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<td>0.8</td>
<td>0.8</td>
<td>0.548(0.0%)</td>
<td>0.548(0.0%)</td>
<td>0.548(0.0%)</td>
<td>-2.095(0.0%)</td>
<td>2.094(0.0%)</td>
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</tr>
<tr>
<td>0.9</td>
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<td>0.549(0.0%)</td>
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<td>0.549(0.0%)</td>
<td>-2.094(0.0%)</td>
<td>2.094(0.0%)</td>
<td>0.569(0.0%)</td>
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<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.572(3.9%)</td>
<td>0.548(0.3%)</td>
<td>0.547(3.0%)</td>
<td>-2.055(1.9%)</td>
<td>2.115(1.0%)</td>
<td>0.622(0.4%)</td>
</tr>
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REFERENCES


About One Approach to Intelligent Managing of Health Specialists Labor Market

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Abstract— Paper illustrates specific features of the health specialists (HS) labor market, which dictate the variance of fuzzy conditions of demand and supply of HS and the multiple-choice pattern of their reconciliation. Levels of modelling of the supply and demand interaction in the HS labor market are singled out. Task formulation and the purpose of managing the demand and supply of HS are discussed. A microlevel model of supply and demand management in the HS labor market based on fuzzy situation analysis and fuzzy pattern recognition is proposed.

Keywords— health specialists labor market, supply and demand, demand model, supply model, situational management, fuzzy reference and actual situations, fuzzy situation recognition.

I. INTRODUCTION

The results of health system activity and quality of medical service rendered to the population completely depend on quality and quantity of health specialists (HS). Therefore, the improvement of medical staff stock and raise of health specialists professional level are important challenges the special attention of each country and generally of World Health Organization (WHO) is given to [1–3]. Currently great significance is attached to highly qualified staff training, additional training for perfection of professional qualities, knowledge and skills of health specialists, staffing and improvement of health quality indicators.

Despite all abovementioned, the tendency of staff shortage, personnel decrease is now observed [4–7]. It is announced that number of staff shortage in USA for 2020 is prognosticated to be 85000 people, and for 2025 the demand and supply will gain the upper hand from 46000 to 90000 [8]. The number of doctors per 10000 people for 2011–2014 has decreased in Ukraine from 49 to 48, in Belorussia – from 54 to 39, in Azerbaijan – from 37 to 35 [9]. In Turkey the number of people per a doctor is 595, whereas this indicator equals 262 in Germany, 203 in Ukraine, 290 in Azerbaijan.

Under the total number of doctors it is provided to take into account all highly-educated doctors who work in treatment, sanitary, social security institutions, scientific and research institutes, postgraduate education training and other health bodies.

Health specialists also include nursing staff (paramedic, obstetrician, nurse). Most of world countries state about the shortage of nursing staff [5]. Despite the doctor/nurse ratio number in Finland equals 1:4.3, in Norway –1:4.7, and in Denmark –1:5.6, these countries still announce the fact of nursing staff shortage [6], as in Britain nurse shortage number was presented up to 35000, and in Finland up to 100000. One of the factors generating this problem is application of information and communication technologies, as well as modern innovative medical technologies in medical sphere, formation of e-health, and it reasons the partial decrease of demand for doctors and increase of demand for nursing staff [10, 11].

Thus, present picture in the sphere of doctor and nursing staff displays the excess of demand over the supply in health specialist labor market, and it makes the issues of regulation and management of demand and supply for health specialists essential at governmental and WHO level [1–4]. Successful solution of this problem requires complex approach to the problem, and development of comprehensive strategy encompassing staff compensation, working conditions, their recruitment and retention issues. Still, there is not any standard model in this direction as well as any country to borrow its “best practice” in order to find appropriate problem solution to the stated issue. According to the results abovementioned issues in health specialist policy have been partially embraced in such countries leading in the medical sphere as England, Belgium, Germany, Ireland, Spain, Lithuania, Slovenia, Finland, Australia and Canada. In these countries necessary source for monitoring of health specialist labor market is availability of an information base maintaining reliable, precise and new data.

II. SPECIFIC FEATURES OF THE HEALTH SPECIALISTS LABOR MARKET

Thus, here are the following challenges to define demand and supply for health specialists:

- What will be future short-, medium- and long-term perspectives for demographic, epidemiological, social and cultural characteristic features of the population;
- Increase of which chronic illnesses, psychological states is prognosticated, and emerging probability of new future diseases in the result of migration flow and climate changes;
- What are the requirements for appropriate future medical service;
- What will citizens’ and users’ requirements be, who will be financing appropriate medical services;
- What kind of specialists and their amount (general practitioner, specialist physicians, paramedics, nurses and others) will be required; what responsibilities and
education of the health specialists together with their compensation rates will be in demand.

In order to find the answers to all abovementioned questions and in the development of correct staffing policy the priority is given to sociological survey method, initiating by WHO from 1990. Topicality of this approach reasoned by the lack of scientific methodology in this field, and shortage of scientific works devoted to this issue.

The new demands on health specialists (HS) emphasize a strong ability to adapt to change and innovations, flexibility, multifaceted skills, mobility, and ability to switch between different areas of activity, which correspondingly require continuous updating of professional knowledge and skills by means of both formal and informal education [12, 13].

However, academic publications have failed to properly focus on the system analysis of the HS labor market and the development of adequate technology and support techniques for managerial decision making in reconciling the supply and demand to reflect the specific features of this sector of the economy and the preferences of its main factors.

The specific features of the HS labor market, the uncertainty of information flows about its state, the much-varied profile of data on HS and the difficulties of measuring it, and the ambiguity of indicators characterizing it predetermine the variety of possible fuzzy states of supply and demand for HS and the multioption pattern of reconciling them. Comparisons and evaluations of these conditions and the choice of the reconciliation policy can be efficiently accomplished with the use of intellectual methods and technologies. The latter help to integrate the versatile information on the supply and demand conditions and facilitate the development of a set of alternatives for managerial decisions and the selection of the most efficient one among them. Management in such systems is considered as a process of identification of the demand and supply condition at a given point in time and decision making suitable in the current situation.

III. MODELING THE INTERACTION BETWEEN SUPPLY AND DEMAND IN THE HS LABOR MARKET

The rise of an information economy emphasizing knowledge as its major value produces a significant influence on labor market deformations. The emphasis shifts toward human resources and the creative aspect of activities, which modifies the basic foundations of a “transaction” in the supply and demand relationship [14, 15].

Nowadays, it is impossible to gain the maximum results from an employee with minimal expenses on his/her development. No expectation is warranted of a creative approach to job tasks or quality level of performance without considerations for the HS preferences (aspirations, interests, and motivations) facilitating his or her professional and often personal development [16, 17].

The task of modeling and managing the interaction between demand and supply in the market for HS can be considered at micro and macro levels. The micro level identification of the supply and demand conditions is viewed from the point of individual subjects in the HS labor market and their behaviors and strategies. At the macro demand level, the basic unit is an enterprise because it is at the enterprise level that the demand for HS is shaped in terms of structure and volume, as well as requirements regarding professional and personal competencies. In this case, the task of defining the level of conformity between supply and demand consists in the development of efficient selection and recruitment of HS.

At the macro level, the task of modeling and managing the interaction between demand and supply in the HS labor market, depending on the objectives, comes to balancing the supply and demand for HS within different territorial and geographic areas (at the industrial, regional, and nationwide levels, etc.).

This paper analyzes the supply and demand relationship in the HS labor market at the micro level. Success in performing job functions depends on the HS intellectual potential, level of certain professional and personal competencies, willingness to properly employ them in the workplace, and desire and ability to expand and update professional knowledge and experience in line with functional requirements. Against this context, it seems worthwhile to address the labor market as an intellectual environment [18], where the commodity is knowledge, abilities, and skills.

By intellectual smart management of the HS labor market, the authors mean managerial decision making to bring down the imbalance between the demand for HS and their supply, which comes to a choice between possible alternatives of the supply and demand reconciliation policy toward solutions that will satisfy as fully as possible the aims and conditions of the objectives set and the needs, preferences, interests, aspirations, and capabilities of the key market subjects, i.e., employers and HS, while bringing down the gap between the demand and supply as much as possible.

IV. FORMULATION OF THE PROBLEM

Suppose \( M = Y \), \( K \), \( G \), \( Q \), \( U \) sets the model of demand for HS defining the competence requirements for those applying to a particular position. It represents the system of employers’ preferences for candidates to a particular position expressed as a set of sought competencies of the right candidate and shapes the reference search profile of an HS. Here, \( Y \) is the set of vacancies expressed by candidate requirements for HS positions by employers; \( K = (L, C) \) is the set of basic competencies characterizing HS, comprising the set \( L \) of personal competencies required for working in HS and the set \( C \) of professional competencies reflecting the required functional abilities for filling a particular vacancy; \( G \) is the system of the employer preferences with respect to levels of particular measures;
\[ Q : V : K \cdot U^p \rightarrow G \] is the decision rule (evaluation model) for mapping the set of preferences to the set of competencies;

\[ U^p \] is the set of conditions offered to candidates applying for IT vacancies.

The supply model \( M_S = \{ S, K, W, Q^*, U^* \} \) reflects actual value of competencies and preferences of each individual HS, thus defining the search profile (professional profile) of HS. Here,

\[ S \] is the set of HS looking for work and aspiring to a particular position;

\[ K = (L, C) \] is the set of personal and professional competencies of an individual HS, a potential candidate to a particular vacancy;

\[ W \] is the set of preferences of an HS;

\[ Q^*: S \cdot K \cdot U^* \rightarrow W \] is the mapping of the set of preferences of an HS to the set of competencies;

\[ U^* \] is the workplace requirements of the HS.

The interaction between the set of reference demand conditions for HS and the set of actual conditions shaping their supply create the set of unique semistructured (fuzzy) situations.

The purpose of managing supply and demand in the HS labor market is to identify (recognize) among the sets of actual search profiles of HS and reference search profiles the particular combination (pair) that shows the highest degree of agreement (convergence) of elements both from the point of preferences (reference requirements) of the employer and from the point of aspirations of the candidate.

With a mechanism available to evaluate supply and demand conditions and the degree of their conformity through the prism of the subjects’ interest in the HS labor market, managerial decisions can be made as to the selection of the best candidate to a position (consequently, the selection of the best job).

In formal terms, the problem of identification of supply and demand conditions can be defined by three components \( D = \{ V, S, R \} \), where:

\[ V \] is the set of vacancies;

\[ S \] is the set of HSs;

\[ R \] is the set of rules defining the relationship between the elements of sets \( V \) and \( S \), i.e., rules helping to compare the descriptions of actual conditions of HS with all reference conditions of the demand side.

The recognition and evaluation of supply and demand conditions take the form of the mapping \( F : D \rightarrow Z \), where \( Z \) is the solution of the problem \( D \) set with the intellectual system as a particular target condition meeting the purpose of recognition and evaluation in a particular situation.

V. PROBLEM SOLUTION

Assume the demand in the HS labor market is defined by the set:

\[ V = \{ V_1, V_2, ..., V_k \} \] or \( V = \{ V_j \}, j = 1, k \) expressed in terms of the number of vacancies;

\[ L = \{ l_1, l_2, ..., l_n \} \] or \( L = \{ l_j \}, j = 1, n \) is the set of personal features required in a candidate to a particular position (job, workplace);

\[ C = \{ c_1, c_2, ..., c_m \} \] or \( C = \{ c_f \}, f = 1, m \) is an open set of competencies sought to fill an HS vacancy;

\[ U^p = \{ u_1, u_2, ..., u_p \} \] or \( U^p = \{ u_f \}, f = 1, p \) is a set of conditions offered to applicants to vacant HS jobs.

The demand model \( V = (L, C) \) can be described by three matrices \( V_L = [l_i]_{kn} \), \( V_C = [c_f]_{km} \) and \( V_U = [u_1]_{ap} \), where every row \( (v_i) \) characterizes individual vacancies in the HS market; columns \( (l_i, c_i) \) represent the constantly expanding base of personality traits and competencies; elements \( l_{kn}, c_{km} \) of \( V_U \) express the level of individual characteristics required to fill the vacancy at the given time \( t \); and \( u_{ap} \) are the values of measures characterizing the conditions proposed to applicants for particular vacancies. Competency weights can also be taken into account; i.e. \( \omega = \{ \omega_1, ..., \omega_m \} \) is the set of weights of personal competencies, and \( L = \{ l_j \}, j = 1, n \); \( \omega = \{ \omega_1, ..., \omega_m \} \) is the set of weights of professional competencies \( C = \{ c_f \}, f = 1, m \).

The degree of conformity between vacancy \( V_i \) and \( l_{ij} \) and \( c_{jfr} \) is defined as fuzzy sets with membership functions

\[ \mu_{h_i}(V_i) : V \times L \rightarrow [0,1], \quad \mu_{c_{jfr}}(V_i) : V \times C \rightarrow [0,1] \] expressing the levels of individual competencies required to fill the vacancy as set by the employers.

Simultaneously, the conditions proposed to applicants are described by matrix \( V_U = [u_1]_{ap} \), where membership functions \( \mu_{h_i}(V_i) : V \times U \rightarrow [0,1] \) represent fuzzy degrees of factors representing the conditions of employment.

Assume the supply in the HS labor market is given as set \( S = \{ S_1, S_2, ..., S_q \} \) of HS looking for work and aspiring to a particular vacancy;

\[ L = \{ l_j \}, j = 1, n \] is the set of actual competencies characterizing HS;

\[ C = \{ c_f \}, f = 1, m \] is the set of actual competencies in each individual applicant to a vacancy;

\[ U = \{ u_f \}, j = 1, p \] is the set of preferences of an HS expressed as his/her requirements for an HS vacancy.

The supply model \( S = (l, C) \) is also given as three matrices \( S_L = [l_{kn}], S_C = [c_f]_{km} \) and \( S_U = [u_1]_{ap} \), where each row \( (S_q) \) characterizes individual candidates to proposed
vакансий в HS job market; columns \( l_{i,n}, c_{m} \) reflect the constantly expanding base of personal traits and competencies; elements \( l_{i,n}, c_{m} \) are the levels of individual attributes required to fill a vacancy; and \( u_{i,n} \) are the values of measures describing the HS requirements for a vacancy.

The degree of competency by an HS \( S_i \) is defined as follows:

\[
\mu_{ls}(S_i) : S \times L \rightarrow [0,1], \quad \mu_{cs}(S_i) : S \times C \rightarrow [0,1] \tag{2}
\]

The HS requirements for a vacancy are expressed by the matrix \( S_{i,v} = [l_{i,n}, c_{m}] \), and \( \mu_{ls}(S_i) : S \times U \rightarrow [0,1] \) reflects fuzzy measures of the IT specialist’s requirements.

In fact, there are two sets of fuzzy situations describing the conditions of demand \( \widetilde{V}_k \) and supply \( \widetilde{S}_q \) in the HS labor market:

\[
\widetilde{S}_q = \left< \mu_{ls}(S_q) \right>, \quad \widetilde{V}_k = \left< \mu_{cs}(V_k) \right> \tag{3}
\]

Here, set \( \widetilde{S}_q = \left< \mu_{ls}(y) \right> \) accounts for fuzzy reference situations, and set \( \widetilde{V}_k = \left< \mu_{cs}(y) \right> \) accounts for fuzzy real situations.

For the purpose of managing supply and demand in the HS labor market, the problem of identification of the supply and demand conformity and subsequent hiring decision can reasonably be posed as a task of fuzzy profile recognition and evaluating the degree of fuzzy conformity of situations by measures and their levels. The search and decision making in these situations comes to comparisons of each fuzzy search profile of HS (applicants to one or several particular vacancies) with each reference search profile of employers and to identifying pairs with the highest degrees of convergence. In this setup, making a decision (logical conclusion) on the convergence (alignment) between supply and demand is based on situational management employing steps of evaluating the degree of convergence between two fuzzy situations. Approaches to convergence evaluation between any actual situation and each reference situation can involve single-stage or multistage procedures of identifying the degree of fuzzy inclusion of situation \( \widetilde{S}_q \) in fuzzy situation \( \widetilde{V}_k \), degrees of fuzzy equality of \( \widetilde{V}_k \) and \( \widetilde{S}_q \) and fuzzy community of \( \widetilde{V}_k \) and \( \widetilde{S}_q \), and other measures of convergence [19, 20].

VI. POSSIBLE SCENARIOS OF SUPPLY AND DEMAND IN THE HS LABOR MARKET

After the identification of the most acceptable employer (decision maker) – HS “pair” is completed on the basis of the degree of convergence among the sets of actual and reference search profiles, several possible scenarios are possible:

**Scenario 1.** One vacancy (employer request) – one applicant (HS). In this case, if the degree of fuzzy convergence between two situations (reference search profile and candidate’s search profile) is not lower than the employer’s set threshold, then the decision is made to hire.

**Scenario 2.** The employer’s preferences are met by several applicants (HS) at an acceptable degree of convergence of two fuzzy situations. They form a subset of fuzzy situations (alternatives), and the most suitable one should be selected.

In this case, the employer acting as an expert (decision maker) can be offered the following methods of decision making [21, 22]:

(a) compare the degrees of convergence of reference and actual situations by the significance levels of the criteria characterizing the applicants to the vacancy and make a decision based on the convergence in the more significant criteria;

(b) expand the list of evaluation criteria, further define input situations, and repeat the procedure of recognition;

(c) reduce the problem to multicriterion choice of the best solution (alternative) taking into account the relative significance of criteria characterizing HS.

**Scenario 3.** Several employers who are interested in hiring of one HS are identified. A reverse problem occurs in this case: a subset of fuzzy reference situations (alternatives) is given in the form of proposed vacancies of different employers with fitting conditions, from which the HS has to choose in accordance with his preferences. In this scenario, the decision maker role lies with the IT HS who can:

(a) compare the degrees of convergence between his aspirations and the criteria defining hiring conditions and make a decision based on the convergence of the most significant criteria;

(b) expand the list of criteria for workplace evaluation, further define input situations, and repeat the recognition procedure;

(c) reduce the problem to a multicriterion choice of the best solution (alternative) taking into account the relative significance of criteria characterizing workplaces.

VII. CONCLUSION

The proposed method is one of the possible options to help employers make reasonable hiring decisions to fill vacancies. The need for such assistance is dictated by a number of factors including the dynamic patterns of the business environment, the narrowing life cycles of implementing new ideas and technologies, and the need for systematic implementation of innovations to maintain competitive strength of the organization. In such circumstances, modern employers must constantly adapt their solutions to constantly changing managerial situations. Moreover, nowadays, the share of decisions to be made in uncertain and unconventional situations is rising significantly at all levels of management. While human resources are the main factor of competitive strength for organizations, the issues of support of decision
making in managing staff and its intellectual potential have gained strategic importance.

REFERENCES


Determining Effects of a Flexible Structure and Non-Random Road Irregularity on Passenger Comfort Using a Quarter Car Model

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Abstract— In this study, coupled interaction of a simply supported Euler-Bernoulli bridge beam with a quarter car travelling with a constant speed on the bridge is presented. Motion equation of the coupled system is derived from Lagrange equations using the kinetic and potential energies of the both system at the contact point. The obtained set of ordinary differential equations is solved in time domain with a special software prepared by computer using the fourth order Runge-Kutta integration method. For special dimensions of the non-random irregularities on the bridge beam, the effect of the irregularity including with the effect of flexibility of the beam on the passenger comfort are analysed in terms of ISO-2631 standard.

Keywords— Non-random road profile, Vehicle-bridge-interaction, Passenger comfort, Euler-Bernoulli bridge beam, quarter car model.

I. INTRODUCTION

The dynamic behaviour of structure under the influence of moving loads as an important issue in engineering has taken place in the literature. For analytical solution of various problems of moving loads, the studies [1], [2] are essential in this field. Considering dynamic behaviour of structures under moving loads with variable velocity, [3]–[5] have studied the dynamic behaviour under the influence of accelerating mass on beams of different types. On a flexible structure without neglecting the effects of damping and inertia of the mass is a moving mass problem and some accurate solutions of these kind of problems using Finite element method (FEM) can be found in [6]–[9]. Moving mass problems in defence systems, for the interaction projectile and barrels are applicable and studies [10]–[13] are significant for the forced vibrations of the barrels due to the projectile and barrel interaction. One of the main applications of the vehicle bridge interaction problems that are the studies in this field are generally divided into nine categories. The effect of the suspension systems, road surface roughness effects, bridge length, the vehicle braking, the vehicle mass, vehicle speed, bridge damping, bridge unit length of the mass, the effect of the acceleration of the vehicle [14]. Despite The early simple cases of a moving concentrated force on a simply supported beam with constant speed [1], the vehicle bridge interaction particularly in bridge engineering applications, are quite important. The first studies in the literature in this area is focused the dynamics of bridges but vehicle dynamics is neglected [15], [16]. Later moving mass with constant or variable velocity over a railway bridge is an important research topic today and some useful solutions of so simple cases of it can be found in [17]. For evaluating the vehicle, bridge interaction in terms of passenger comfort of a vehicle on a flexible structure for constant velocity has been given in [18]. One of the major applications of train / rail interaction, for example, [19] proposed a two-axle vehicle on an Euler-Bernoulli beam the bridge interaction using finite element model. The other Wheel/rail interaction applications using FEM can be found in [20]–[22]. Another research interest in this field is on the effect of road roughness.

In general, depending of the accuracy of the modelling of both vehicle and bridge models, the vehicle-bridge interaction problems are very complicated in order to analysing the interaction considering the passenger comfort. In this study, the effects of basic parameters that affect the system are studied using a quarter car model.

II. MATHEMATICAL MODELLING

The quarter-car model with two degrees of freedom contains vehicle body and axle with masses \( m_1, m_2 \), and connecting elements that consist of springs and dampers with the same features and linear characteristics. In the model shown in Figure 1, \( k_1, k_2 \), represent, respectively, the stiffness of the tire and suspension.
Symbols $c_1$, $c_2$, on the other hand, represent, respectively, the damping coefficients of the tire, suspension. In addition, the mass of the suspension system is included in the mass of the vehicle body. The parameters $y_1$ and $y_2$ represent vertical movement of the tires at their point of contact with the bridge. These movements are affected by the deflection of the tires at their point of contact, and the roughness of the road at the same points. The vertical movement of the bridge $w_b(x, t)$ represents the deflection of any point $x$ on the beam of the bridge at time $t$, relative to a reference point on the left-hand support of the beam. The symbol $v$ represents the constant velocity of the vehicle as it moves from the left end of the beam to the right end. The function $r(x)$ represents the roughness of the bridge surface, and will be explained in detail in the following sections.

In the formulation for the VBI analysis following assumptions will be adopted:

- The bridge is modelled as a simple supported beam based on Euler-Bernoulli theory.
- The vehicle was modelled four and six DOF as lumped parameter.
- Only one car was accepted moving on the bridge with constant velocity $v$.
- The car’s wheels are always in contact with the bridge. There are not any jumping involved.

With these assumptions, the kinetic and potential energy of the vehicle-bridge-passenger interaction, as shown in Fig. 1a, is expressed as follows respectively:

$$E_k = \frac{1}{2} \int_0^L \mu \left[ \dddot{w}_i (x,t) + \left( m_i \ddot{y}_i + m_i \dot{y}_i^2 \right) \right] dx, \quad (1)$$

$$E_p = \frac{1}{2} \int_0^L \left[ \rho_i v_i(x,t) + \left\{ \left( y_i - w_i(x,t) \right) \dddot{y}_i + k_i \left( y_i - y_i \right) \dot{y}_i \right\} \right] dx, \quad \text{for} \quad i = 1, 2, 3, 4, \quad (2)$$

Approaches, such as the principle of virtual work, Hamilton’s principle, and D’Alembert’s principle can be used for the equation of motion of the system, as shown in Fig. 1a. This study uses Lagrange’s equations, formed using the kinetic energy and potential energy equations of the vehicle-bridge integrated system, and the mode expansion method. The Galerkin equation for the deflection $w_b(x, t)$ of any point $x$ on the beam at time $t$ is expressed as follows:

$$w_i(x, t) = \sum_{i=1}^n \varphi_i(x) \eta_i(t), \quad (3a)$$

$$\ddot{w}_i(x, t) = \sum_{i=1}^n \ddot{\varphi}_i(x) \eta_i(t), \quad (3b)$$

$$w^*_i(x, t) = \sum_{i=1}^n \varphi_i^*(x) \eta_i(t), \quad (3c)$$

$$\varphi_i(x) = \frac{1}{\sqrt{2L}} \sin \left( \frac{i \pi x}{L} \right), \quad i = 1, 2, …, n. \quad (4)$$

Rayleigh dissipation function for the vehicle-bridge integrated system is expressed as follows:

$$D = \frac{1}{2} \left[ c \dot{y}_i^2 + c_i \left( \ddot{y}_i - w_i(x, t) \right) + c_i \left( \ddot{y}_i - \ddot{y}_i \right) \right], \quad (5)$$

In Eq. (5), $c$ is the equivalent damping function for bridge beam. In addition, the Lagrange equation ($L = E_k - E_p$) of the system is equal to the difference between the kinetic energy and the potential energy. If the Lagrange equation is rearranged for six independent coordinates, the following is obtained:

$$\frac{d}{dt} \left( \begin{array}{c} \frac{\partial L}{\partial p_i(t)} \\ \frac{\partial L}{\partial p_i(t)} + \frac{\partial R}{\partial p_i(t)} \end{array} \right) + \frac{\partial R}{\partial p_i(t)} = 0, \quad k = 1, 2. \quad (6a)$$

$$\frac{d}{dt} \left( \begin{array}{c} \frac{\partial L}{\partial \eta_i(t)} \\ \frac{\partial L}{\partial \eta_i(t)} + \frac{\partial D}{\partial \eta_i(t)} \end{array} \right) + \frac{\partial D}{\partial \eta_i(t)} = Q, \quad i = 1, 2, 3, 4. \quad (6b)$$
The motion equation of the vehicle-bridge-passerger model with six degrees of freedom shown in Fig. 1 is obtained by using the orthogonality condition and the Galerkin approach expressed for beam deflection (Eq. (3)). Motion equations for the vehicle axle, the vehicle body are expressed, respectively, as follows:

\[ m_1 \ddot{y}_1 - k_1 (y_1 - y_t) + k_1 (y_t - y_i (x,t)) - c_1 (\dot{y}_1 - \dot{y}_t) + c_1 (\dot{y}_t - \dot{w}_1 (x,t)) = 0 \]  

(7a)

\[ m_2 \ddot{y}_2 + k_2 (y_2 - y_1) + c_2 (\dot{y}_2 - \dot{y}_1) = 0 \]  

(7b)

The effects of road profiles with roughness of varying location, width, depth, and number on vehicle dynamics were examined. Non-random roughness as shown in Fig.12 is divided into two categories: periodical and discrete. In mathematical terms, non-random irregularities are expressed as in Eq. (8) [19]:

\[ r_j (x) = \frac{1}{2} \zeta (1 - \cos 2\pi x / \gamma) \]  

(8)

Here \( \zeta \) represents the depth or height of the road defect, and \( \gamma \) represents its width. Eq. (8) is expressed as a series as in Eq. (9).

\[ r_j (x) = \begin{cases} 
\frac{1}{2} \zeta \left(1 - \cos \frac{2\pi (x - C)}{\gamma}\right), & \text{for } C \leq x \leq C + \gamma \\
0 & \text{elsewhere},
\end{cases} \]  

(9)

\[ C = B + k(A + \gamma), \quad k = 0, 1, \ldots, N_i 
\]

(10)

\[ N_i = (L_d - B) / (A + \gamma), \]  

(11)

Here \( B \) is the distance between the defect on the bridge and the left end of the bridge, which is taken as the reference point, \( L_d \) represents the distance between two consecutive road defects, and \( N \) refers to the number of defects.

III. NUMERICAL EXAMPLES

In this study, in order to analyse interaction of vehicle-bridge-road in Figure 1, the parameters of the vehicle and bridge listed in Table 1 are chosen. Considering various conditions the interaction between the vehicle-bridge is represented by a system of ordinary differential equations; and then it is solved using the fourth order Runge-Kutta method and a special code written in MATLAB. On a flexible structure like a bridge, the effect of the non-random irregularity has been investigated using different cases that are given in Table 2. Case 1 and Case 2 are shown in Figure 2.

### Table 1

<table>
<thead>
<tr>
<th>Bridge and Bridge Parameters</th>
<th>Value</th>
<th>Vehicle Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>L (m)</td>
<td>100</td>
<td>m_1 (kg)</td>
<td>227.55</td>
</tr>
<tr>
<td>E (Gpa)</td>
<td>207</td>
<td>m_2 (kg)</td>
<td>1944</td>
</tr>
<tr>
<td>l (m^3)</td>
<td>0.174</td>
<td>k_1</td>
<td>85439.2</td>
</tr>
<tr>
<td>( \mu ) (kg/m)</td>
<td>20000</td>
<td>k_2</td>
<td>202230</td>
</tr>
<tr>
<td>c (Ns/m)</td>
<td>1750</td>
<td>c_1</td>
<td>2190</td>
</tr>
<tr>
<td>( \zeta ) (m)</td>
<td>12.5</td>
<td>c_2</td>
<td>29.2</td>
</tr>
</tbody>
</table>

For the two cases, the vertical responses of the axle and body are presented in Figure 3, for a constant speed of the vehicle \( v=25 \) m/s. In the Case 1, the vehicle has just past over the bump after 0.5 second from the start. In the second case, that represents three successive bumps, the vehicle is over the bumps at the time of 0.5, 0.56, and 0.62 seconds respectively. In addition to the effect of the flexible bridge, the effects of the bumps can be easily noticed from Figure 3.

The effect of the height of the bump \( \zeta \) on the responses of the vehicle components is given in Figure 4. For three value of \( \zeta \) that are 1, 4, and 7 cm the responses of the axle are 1, 3.5, and 6 mm respectively, the responses of the body are smaller when compared to the responses of the axle, as can be seen from Figure 4 at the right.

### Table 2

<table>
<thead>
<tr>
<th>Bridge Parameters</th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (m)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>B (Gpa)</td>
<td>12.5</td>
<td>12.5</td>
</tr>
<tr>
<td>( \zeta ) (m)</td>
<td>0.085</td>
<td>0.085</td>
</tr>
<tr>
<td>( \gamma ) (kg/m)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>N_i (Ns/m)</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
For the Case 2, Figure 5 shows the responses of the axle and body for the same height of the successive bumps.

![Figure 3](image1.png)

**Fig. 3** The effect of non-random road roughness upon vehicle displacement for time step size $\Delta t=0.001$, vehicle velocity $v=25$ m/s (a) vehicle axle displacement; (b) vehicle body displacement (m).

![Figure 4](image2.png)

**Fig. 4** The effect of depth of non-random road roughness upon vehicle displacement for time step size $\Delta t=0.001$ and Case 1, vehicle velocity $v=25$ m/s (a) vehicle axle displacement; (b) vehicle body displacement (m).
Fig. 5 The effect of depth of non-random road roughness upon vehicle displacement for time step size Δt=0.001 and Case 2, vehicle velocity v=25 m/s (a) vehicle axle displacement; (b) vehicle body displacement (m).

IV. CONCLUSIONS
In this study, a vehicle-bridge and road interaction is presented using a two DOF quarter car. The conditions of the road have been considered using definite non-random irregularities. Beside the effect of the flexible structure, the effects of the bumps are also important for the responses of the vehicle components and passenger comfort where it may be important in vehicle design, transportation safety, and bridge health and usage life.

REFERENCES

Abstract—This study aims to present the statistical process control (SPC) on ash content data of -10+0,5 mm product of heavy medium cyclone device at Dereköy coal washing plant in Soma, Turkey. The ash content data were determined both non-normally distributed and autocorrelated. This research explains the ways how SPC can be applied for this kind of data in terms of ensuring data normality by Johnson transformation and removing autocorrelation by ARIMA(2,0,0) or AR(2) time series model in order to proper application of SPC on ash content data.

Keywords—Coal preparation, ash content, statistical process control, Johnson transformation, ARIMA

I. INTRODUCTION

About 90% of Turkey’s coal resource are low quality lignite which have lower calorific value and higher ash and sulphur contents and it corresponds to approximately 11.56 billion tons [1]. In order to increase their qualities, the lignites are subjected to washing process at coal preparation plants which are mainly based on heavy dense separation methods.

During an industrial production stage, a suitable quality control of a product produced is essential in almost whole industrial field. Statistical process control (SPC) is one of the most known and preferred method used for this aim since its many advantages [2]. The SPC is practical and simple to apply. The SPC have two basic assumptions on data investigated. During the application of SPC, the data are assumed to have normal distribution and independent, i.e. not autocorrelated. Many authors have reported that if these assumptions are verified, the SPC charts generated by data assumptions give different results than those considering them [2-5]. In literature, many researchers have shown that both data normality [6-12] and autocorrelation between consequent data [13-18] had a reverse effect on the performance of SPC charts and should be taken into account.

The SPC is also applied on the mining field and mineral processing products in order to monitor and control the quality of product. Some of these applications were related to coal preparation [19-21]. Previous studies have shown that both data normality and autocorrelation have also affected the SPC results when applied on mining and mineral processing field [22-29].

Ash content is one of the most known and preferred parameter for the coal quality. The moisture, calorific value, organic and inorganic sulphur content etc. are also used to quantify a coal product quality.

In this study, the SPC was applied on the ash content of -10+0,5 mm product of heavy dense cyclone. Since the ash content data were determined as both nonnormally distributed and also autocorrelated, Johnson transformation method was applied successfully to the ash data and then the autocorrelation was successfully removed by ARIMA(2,0,0) or AR(2) time series model prior to SPC.

II. MATERIAL AND METHOD

The data used in this research were obtained from Dereköy coal washing plant in Soma, Turkey. The flowsheet of the plant which was modified from Şengül [30] is presented in Fig. 1. Ash content data of -10+0,5 mm product produced by the first heavy dense cyclone which is shown with a star symbol in Fig. 1 were used as data set to apply SPC. Detailed information about the coal washing process shown on the flowsheet has been already given in elsewhere [31] and therefore will not be repeated again in this work. Totally 356 data obtained in 2010 were used and for the evaluation of data both trial versions of Minitab 16.0 and Statgraphics XV softwares were used.

Fig. 1 Simplified flowsheet of Dereköy coal preparation plant (Modified from Şengül [30]).
III. RESULTS

A. Properties of ash content data

Normality check results showed that the original ash content data was not obeying normal distribution. According to the normal probability plot and normality test results presented in Fig. 2, p value of the test was <0.005 with Anderson Darling (AD) value of 3.593 indicating that ash content data distribution deviated from normal distribution. In order to fit the data to the normal distribution, Johnson transformation was found the best method. Fig. 2 also shows probability plot of Johnson transformed ash data the transformation summary and equation with normality check results. The unbounded system (SU) Johnson transformation gave the best transformation equation for the ash data evaluated since this transformation has a p value of 0.836 (>0.05) with AD value of 0.219. The transformation equation obtained was:

\[ z = -0.799 + 1.712 \sinh^{-1}(x - 7.961) / 2.083 \]  \hspace{1cm} (1)

Where; \( z \): Johnson transformed ash value, \( x \): raw ash value.

For raw ash content, the following Eq. 2 can be used to back transform the ash value \( (x) \) corresponding Johnson transformed ash value of \( z \) by solving Eq.1:

\[ x = 7.961 + 2.083 \left( e^{(2z+0.799)/1.712} - e^{(2z+0.799)/2} \right) \]  \hspace{1cm} (2)

![Probability plots of original and Johnson transformed ash data](image)

Fig. 2. Probability plots of original and Johnson transformed ash data the best transformation equation and summary

Fig. 3 presents the time series plots of original and Johnson transformed ash content comparatively. As seen in Fig. 3, both the original and transformed ash data were stationary and there was no need to take difference process to make the data stationary.

![Time series plots of original and Johnson transformed ash data](image)

Fig. 3 Time series plots of original and Johnson transformed ash data

B. Autocorrelation and ARIMA model

The transformed ash data were checked if there were any autocorrelation between consequent ash content data values. Table 1 summaries the autocorrelation values for 24 lags. As seen from Table 1, the transformed ash data had two important autocorrelation at lags 1 and 2. Graphical representation of autocorrelation of Table 1 is given in Fig. 4. As seen clearly, there are two important spikes at lag 1 and 2 and then between the 95% confidence intervals.

<table>
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<tr>
<th>Lag</th>
<th>Autocorrelation</th>
<th>Std. Error</th>
<th>Lower 95.0% Prob. Limit</th>
<th>Upper 95.0% Prob. Limit</th>
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<tbody>
<tr>
<td>1</td>
<td>0.367099</td>
<td>0.0529999</td>
<td>-0.103878</td>
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<td>2</td>
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<tr>
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</tr>
<tr>
<td>4</td>
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<td>0.0623327</td>
<td>-0.12217</td>
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<tr>
<td>5</td>
<td>0.115394</td>
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<tr>
<td>6</td>
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<tr>
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<tr>
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<tr>
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<td>-0.125994</td>
<td>0.125994</td>
</tr>
<tr>
<td>13</td>
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<td>0.125948</td>
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<tr>
<td>14</td>
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<tr>
<td>15</td>
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<tr>
<td>19</td>
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<tr>
<td>20</td>
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<tr>
<td>21</td>
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<td>-0.127329</td>
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<td>22</td>
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<td>-0.127483</td>
<td>0.127483</td>
</tr>
<tr>
<td>23</td>
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<td>0.0651999</td>
<td>-0.128221</td>
<td>0.128221</td>
</tr>
<tr>
<td>24</td>
<td>-0.0691455</td>
<td>0.0659237</td>
<td>-0.129208</td>
<td>0.129208</td>
</tr>
</tbody>
</table>
In order to remove the autocorrelation, the best time series model was determined. It was found that ARIMA(2,0,0) or AR(2) model was the best model for the Johnson transformed ash data of -10±0.5 mm product. The details of determination of ARIMA type time series model have been already well documented from the literature [32-33] and therefore more information can be found there and from literature listed therein.

The AR(2) model summaries are given in Table 2. From these parameters, the next ash content can be estimated by the previous ones and the estimation equation is as the following:

\[ X_t = \delta + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \alpha_t \]  \hspace{1cm} (3)

Where, \( X_t \) is the observation at time \( t = 1, 2, 3, \ldots \), \( \delta \) is constant calculated from \( \mu(1-\phi_1 - \phi_2) \), \( \mu \) is the mean of the process, \( \phi_1 \) and \( \phi_2 \) are autoregressive parameters, \( \alpha_t \) is the random noise at time \( t = 1, 2, 3, \ldots \), assumed to be independent and identically distributed (i.i.d) normal \( (0, \sigma_\alpha^2) \). \( \sigma_\alpha^2 \) is the variance of random noise (white noise variation). From Eq. 3 and Table 2, the following Eq. 4 of AR(2) time series model can be used to predict future ash content from the previous data:

\[ X_t = 0.0102 + 0.3339 X_{t-1} + 0.0935 X_{t-2} \]  \hspace{1cm} (4)

For a reasonable time series model, the residuals (the difference between the actual and predicted values) should be independent and identically distributed (iid). The residuals of AR(2) model was subjected to diagnostic tests for the iid. Fig. 5 shows the residual plots and Fig. 6 gives the autocorrelation plot of AR(2) model which was resulted from diagnostic tests. Both the results of Fig. 5 and Fig. 6 indicated that the model residuals had a mean of zero (0) with 0.9064 white noise variance and distributed normal and independent i.e., not autocorrelated.

**TABLE III**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
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</thead>
<tbody>
<tr>
<td>AR(1), ( \phi_1 )</td>
<td>0.3339</td>
</tr>
<tr>
<td>AR(2), ( \phi_2 )</td>
<td>0.0935</td>
</tr>
<tr>
<td>Mean, ( \mu )</td>
<td>0.0178</td>
</tr>
<tr>
<td>Constant, ( \delta )</td>
<td>0.0102</td>
</tr>
<tr>
<td>WNV*, ( \sigma_\alpha^2 )</td>
<td>0.9064</td>
</tr>
</tbody>
</table>

*: white noise variance

Fig. 4 Estimated autocorrelations for Johnson transformed ash data

Fig. 5 Residual plots of AR(2) model for Johnson transformed ash data

Fig. 6 Autocorrelation function (ACF) of residuals of AR(2) model for Johnson transformed ash content data with 5% significance limits

Fig. 7 Actual and predicted Johnson transformed ash content by AR(2) time series model
C. Individual charts (I-charts) of original and Johnson transformed ash data

Table 3 summarizes the individual chart (I-chart) parameters obtained for the original ash content without data transformation. Fig. 8 gives I-chart plot drawn according to the values in Table 3. Process sigma (\( \sigma \)) was estimated from average moving range (\( \overline{MR} \)) for the sample size of 2. This chat shows us the upper control limit (UCL), central line that is the mean of ash content (CTR) and lower control limit (LCL) when the data were assumed both normally distributed and independent. If these data were used without verification of assumptions, 15 points were beyond the UCL and 2 points were under the LCL as seen in Fig. 8.

<table>
<thead>
<tr>
<th>I-Chart Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>UCL=+3(\sigma)</td>
<td>12.82</td>
</tr>
<tr>
<td>CL=(\overline{X})</td>
<td>9.20</td>
</tr>
<tr>
<td>LCL=-3(\sigma)</td>
<td>5.58</td>
</tr>
<tr>
<td>(\sigma(\overline{MR}/1.128))</td>
<td>1.21</td>
</tr>
<tr>
<td>MR</td>
<td>1.36</td>
</tr>
</tbody>
</table>

![Fig. 8 I-chart of original ash content under normality and independence assumptions](image)

Fig. 8 I-chart of original ash content under normality and independence assumptions

Fig. 9 shows I-chart of ash content after transformation in transformed scale. In this chart, data normality assumption was verified by Johnson transformation however data independence was just assumed i.e., not verified. Four points were beyond the UCL and 3 points were under LCL after normality verification.

![Fig. 9 I-chart of Johnson transformed ash content under independence assumption](image)

Fig. 9 I-chart of Johnson transformed ash content under independence assumption

D. ARIMA control charts of Johnson transformed ash data

ARIMA (Auto Regressive Integrated Moving Range) Charts take into account data independence i.e. autocorrelation between subsequent observations measured [34]. From this point of view, ARIMA charts are contrary to X-Charts. In ARIMA Charts, autocorrelation is determined by a time series model and unusual points are detected by process deviations.

Since AR(2) was found the best time series model to remove autocorrelation, the AR(2) chart is constructed with data vary around the mean \( \mu \) with control limits like I-charts. Process mean, \( \mu \) can be found by AR(2) parameters as;

\[
CL = \mu = \frac{\delta}{1 - \phi_1 - \phi_2} \quad (5)
\]

Since the process is autocorrelated, its standard deviation, \( \sigma_x \), depends on the parameters of time series model and as stated by Bisgaard and Külahçı [5], it is equal to for AR(2) model;

\[
\sigma_x = \sqrt{\frac{(1-\phi_2)}{(1+\phi_2)[(1-\phi_2)^2-\phi_1^2]}} \quad (6)
\]

The standard deviation of random shocks, \( \sigma_z^2 \), i.e. white noise variance in Eq. 6 have been estimated by both the mean squared error (MSE) of fitted AR(2) model and the mean range (MR) of residuals.

In this chart, data are drawn around a centreline located at \( \mu \) with control limits of;

\[
\mu \pm 3\sigma_x \quad (7)
\]

As given in Table 2, Johnson transformed ash data have been simulated well by AR(2) model with, \( \delta = 0.0102, \mu = 0.0178, \phi_1 = 0.3339, \phi_2 = 0.0935 \), where \( \alpha_i \) has mean of 0 and standard deviation of \( \sigma_{\alpha_i} = 0.952 \).

By solving Eq. 6, the variances of Johnson transformed ash content is \( \sigma_z^2 = 1.1671\sigma_x^2 \) which means that it is about 1.17 times larger than the residual white noise variance.

The AR(2) chart parameters where the random noise variance (\( \sigma_z^2 \)) is estimated by average moving range of AR(2) residuals (\( \overline{MR} \)) and then process sigma (\( \sigma_x \)) was calculated by Eq. 6 was 0.96. The generated control charts in these conditions for Johnson transformed ash data is given in Fig. 10. When the Fig. 10 examined carefully, it was seen that there were no out of control points actually compared to Figs. 8 and 9. To give correct decision about a process quality parameter like ash content in our example, one should consider both data normality and autocorrelation. If we only assume instead of verifying them, we would use the Fig. 8 and would conclude that there were 17 points that out of control during the washing of coal by the first heavy dense cyclone in terms of ash content.
When the control limits are determined for long term, mean squared error (MSE) of ARIMA model is used as process sigma, \( \sigma_x [34] \). The ARIMA chart after constructing control chart for long term limits is shown in Fig. 11. In this chart, process sigma, \( \sigma_x \) was estimated by Eq. 6 and white noise variance, \( \sigma_e^2 \) is calculated by MSE of AR(2) model which is given in Table 2. As seen, the chart in Fig. 11 are considerably wider bounds than the charts in Fig. 9 and Fig. 10 since the estimated process \( \sigma_x \) is a function of both white noise or random shock and fitted AR(2) model parameters (Table 2).

The chart type in Fig. 11 was constructed to monitor the long-term behavior of -10+0,5 mm product of first heavy dense cyclone. It is used to determine the process deviations from long-term mean more than expected given the dynamics of the process [34].

Since \( a_t \) is assumed to be independent and identically distributed (iid) normal \((0, \sigma_a)\), control limits of residuals chart in case of process is control are calculated by the following Eq. 9 [3]:

\[
CL = \pm K \sigma_a
\]

Where \( K \) is a constant chosen as 3 usually [3].

The resulted ARIMA residual charts obtained for ash content are shown in Fig. 12a where sigma \( (\sigma_a) \) is estimated from residual mean of moving range \((\bar{MR})\) and in Fig. 12b where \( \sigma_a \) is estimated residual MSE of AR(2) model.

As seen in Figs. 12a number of points beyond \( \pm 3\sigma_a \) limits are 2 when the \( \sigma_a \) is estimated from both \( \bar{MR} \) and On the other hand, there was no out of control points when the \( \sigma_a \) is estimated from MSE of AR(2) model for the AR(2) residuals of Johnson transformed ash data (Fig. 12b).

Since the aim was to reduce the ash content as soon as possible during the coal washing process. Therefore, the out of points beyond LCL cannot be considered uncontrolled process actually. From this point of view, the process can be under control in terms of ash content in 2010.

E. ARIMA residual chart of Johnson transformed ash data

In order to detect unusual points of ash data, ARIMA residuals charts were constructed for several conditions. In ARIMA residuals charts, a time series model is determined to fit data then the autocorrelation is subtracted and finally residuals obtained are monitored [3]. In this research, the residuals are the difference between actual ash values and their forecasts by AR(2) model. The residuals, \( a_t \), can be calculated by rewriting the Eq. 4 [5] as:

\[
a_t = X_t - \phi_1 X_{t-1} - \phi_2 X_{t-2} - \mu (1 - \phi_1 - \phi_2)
\]

IV. CONCLUSIONS

In this research, statistical process control chart was applied to monitor the ash content of -10+0,5 mm product of the first heavy dense cyclone at Dereköy coal washing plant in Soma, Turkey. It was shown that the SPC charts would be incorrect when they are constructed by only assuming the data.
normality and autocorrelation. Both data normality and 
autocorrelation are important properties that should be 
verified prior to generating the SPC charts. Johnson 
transformation achieved normality of nonnormally distributed 
ash content data. AR(2) time series model described the 
autocorrelation best for the transformed ash content data. The 
ARIMA control chart where the process sigma was estimated 
from the mean squared error (MSE) of AR(2) model can be 
used for the long term monitoring in determination of control 
limits of ash content of -10±0.5 mm coal product. In addition, 
the unusual points can be detected by AR(2) residuals 
chart during the production stage of coal produced by the first 
heavy dense cyclone. According to the ARIMA residual 
charts, -10±0.5 mm product can be considered under control 
in terms of ash content in 2010.

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Investigation of Winglet Shape Effect on the Drag and Lift Force of Aircraft Wing

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Abstract—In this study, different winglet shape is investigated to compare lift and drag forces. The computational fluid dynamic (CFD) analysis of three dimensional (3D) flow over wing is used for this examination. Winglets are angled extensions or vertical projections at the tip of a wing. Winglets are used to increase aerodynamic performance of wings. They are widely used on commercial airplanes for the purpose of reducing induced drag, vortices, and increasing lift. Winglets reduce wingtip vortices. Twin tornados (vortices) formed by the difference between the pressure on the upper surface of an airplane's wing and on the lower surface. High pressure on the lower surface creates a natural airflow, which makes its way to the wingtip and curls upward around it. The drag force is generated by pressure distributions over the body surface. Winglet reduce the amount of drag. Efficiency of aircrafts are increased by decreasing drag force and fuel consumption is decreased using winglets. When an aircraft is designed, lift and drag forces must be analyzed and the structural design should be based on these forces. Hence, lift and drag forces on the three dimensional wing, which has different winglet types, are analyzed by using a commercial CFD program ANSYS in this study.

Keywords—Winglet, Aircraft Wing, Computational Fluid Dynamic, Lift Force, Drag Force.

I. INTRODUCTION

Aerodynamic forces, which are lift and drag forces, are occurred on a body, which is immersed in the air due to the relative motion between the body and the air. Aircraft wing generates aerodynamic forces, when it is moving within the air. Drag force can be defined as the force component parallel to the direction of the relative motion. Lift force also can be defined as the force component perpendicular to the direction of the relative motion. In addition, thrust is also aerodynamic force. It can be obtained by propeller or jet engine of aircraft. The other force acting on a wing is weight. The weight is not an aerodynamic force. It is body force. Aircrafts should be design according to these forces.

The effect of a pair of thin stationary winglets on the aerodynamics of a bluff body was studied by the Savage and Larose [1]. The aerodynamic and aeroelastic characteristics of winglet were studied experimentally in terms of the moment coefficients and aerodynamic forces. Rate of change of moment coefficients and aerodynamic forces with angle of wind incidence and the motional aerodynamic derivatives. It was observed that the winglets provided important aerodynamic damping and reduced the sensitivity of the rectangular prism to torsional aerodynamic instability.

Usage of CFD tools by the aerospace field to increase understanding of fluid dynamic and aerodynamic phenomena has been rapidly increasing during the past decade [2]. Also numerical simulation has become a significant and growing aspect of the aircraft design process. Thanks to CFD, dependency on wind tunnel investigations are reduced so consequently design cost is also reduced. As a result of these developments, wing performances are increased using the CFD tools.

A wing is a surface used to produce an aerodynamic force (shown in Fig. 1) normal to the direction of motion by travelling in air or another gaseous medium. A wing is an extremely efficient device for generating lift. Its aerodynamic quality, expressed as a lift-to-drag ratio, can be up to 60 on some gliders and even more. This means that a significantly smaller thrust force can be applied to propel the wing through the air in order to obtain a specified lift [3].

The drag and lift forces using CFD which can also be determined through experiments using wind tunnel testing. The analysis of the two dimensional subsonic flow over a NACA 0012 airfoil at various angles of attack and operating at a Reynolds number of $3 \times 10^6$ was presented. The CFD simulation results showed close agreement with those of the experiments, thus suggesting a reliable alternative to experimental method in determining drag and lift. [4].
A simple method was given for the evaluation of the induced lift by the Eppler [5]. The rollup of the wake is not considered. It probably had less effect than the induced lift, at least for the high aspect ratios of gliders. The results from several parameter variations were presented. They concerned dihedral and winglets as well as sweep back.

A winglet optimization procedure for a Medium-Altitude-Long-Endurance (MALE) Un-manned-Aerial-Vehicle (UAV) was presented by the Panagiotou and friends [6]. Aerodynamic and performance parameters were defined during the conceptual and preliminary design phases. The winglet optimization procedure was a part of the detail design phase. The flow around several winglet configurations was investigated, using CFD. Lift, drag and pitching moment coefficient charts, along with vorticity contours and tip vortex images, were presented.

Design of wing tip devices at high and low speeds was described by Büscher and friends [7]. A comprehensive parameter study was carried out using a rapid aerodynamic prediction tool named Lift and Drag Component Analysis (LIDCA). Adding to an available lifting-line method a databased module for airfoil data was employed that uses results of two-dimensional flow simulations by multidimensional interpolation. The results of the most effective wing tip designs were analyzed at both flight conditions. Also, options for improving the performance at take-off were suggested.

A series of multi-objective winglet shape optimizations were performed to find the Pareto front between the wing aerodynamic drag and the wing structural weight for a wing equipped with a winglet by the Elham and Tooren [8]. The paper discussed the addition of winglets to existing aircraft designs. In order to estimate the aerodynamic and structural characteristics of a non-planar wing, a quasi-three-dimensional aerodynamic solver was integrated with a quasi-analytical weight estimation method inside an optimization framework. The optimization results showed that about 3.8% reduction in fuel weight and about 29M$ reduction in 15 years DOC of a Boeing747 type aircraft can be achieved by using winglets.

II. NUMERICAL STUDY

1) Description of the geometry model

Aircraft wing model is created in SolidWorks. Naca 2415 airfoil (shown Fig. 2) which is asymmetric is used to design wing. The wing has variable chord length and 20 m span length. Boeing 737 wing (shown Fig. 3 and Fig. 4) is modelled with Naca 2415 airfoil.

2) Mesh generation

When fluid flow is analyzed, flow domains are split into smaller sub domains. The governing equations are then discretized and solved inside each of these sub domains. Unstructured mesh which has 711050 cells and 158198 nodes was constructed by the Ansys Mesh generator for the winglet. The meshed area around the wing is as shown in Fig. 5 and meshed winglet is as shown in Fig. 6.
Unstructured mesh which has 709875 cells and 138837 nodes was constructed by the Ansys Mesh generator for the backside winglet. The meshed area around the wing is as shown in Fig. 7 and meshed backside winglet is as shown in Fig. 8 and Fig. 9.

Unstructured mesh which has 599408 cells and 140625 nodes was constructed by the Ansys Mesh generator for the normal flat wing. The meshed area around the wing is as shown in Fig. 10 and meshed normal flat wing is as shown in Fig. 11.

III. NUMERICAL METHOD AND BOUNDARY CONDITIONS

ANSYS FLUENT software which is based on the finite volume method is used to perform numerical calculations. Gravity is to be neglected. Pressure based and steady-state solution methods are selected to perform calculations. Sparat Allmaras is chosen as turbulence model. Momentum is modeled using second order functions. Boundary conditions are set for the different areas of each mesh, such as wall face with zero velocity, symmetry faces, velocity inlet and pressure outlet for the fluid. Density of the air is 1.225kg/m³, and the kinematics viscosity of the air is 1.7894e-5. Free stream velocity of 50 m/s is assumed. All parameters of the above are applied to set for simulations.

IV. ANALYSIS RESULTS

In this section, lift and drag forces of Boeing 737 wing are calculated using CFD analysis at different wing tip types. Static pressure and velocity results are as shown in Fig. 12 and Fig. 13 for the winglet. Static pressure and velocity results are as shown in Fig. 14 and Fig. 15 for the backside winglet. Static pressure and velocity are as shown in Fig. 16 and Fig. 17 for normal flat wing.
Fig. 12. Pressure (Pa) value of winglet

Fig. 13. Velocity (m/s) value of winglet

Fig. 14. Pressure (Pa) value of backside winglet

Fig. 15. Velocity (m/s) value of backside winglet

Fig. 16. Pressure (Pa) value of normal flat wing

Fig. 17. Velocity (m/s) value of normal flat wing
Lift force and drag force values are as shown in Table 3 and CL/CD ratios are as shown in Table 2 and CD and CL values are as shown in Table 1 respectively. Also, lift and drag force graphic is as shown in Fig. 18.

### TABLE I. CL AND CD VALUES ACCORDING TO WING TIP TYPE

<table>
<thead>
<tr>
<th>Wing Tip Type</th>
<th>CL</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winglet</td>
<td>0.0856</td>
<td>0.0217</td>
</tr>
<tr>
<td>Normal flat wing</td>
<td>0.0838</td>
<td>0.0231</td>
</tr>
<tr>
<td>Backside winglet</td>
<td>0.0843</td>
<td>0.00979</td>
</tr>
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### TABLE II. CL/CD RATIO ACCORDING TO WING TIP TYPE

<table>
<thead>
<tr>
<th>Wing Tip Type</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Winglet</td>
<td>3.945</td>
</tr>
<tr>
<td>Normal flat wing</td>
<td>3.628</td>
</tr>
<tr>
<td>Backside winglet</td>
<td>8.611</td>
</tr>
</tbody>
</table>

### TABLE III. LIFT AND DRAG FORCE ACCORDING TO WING TIP TYPE

<table>
<thead>
<tr>
<th>Wing Tip Type</th>
<th>Drag Force (N)</th>
<th>Lift Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winglet</td>
<td>230.94</td>
<td>910.97</td>
</tr>
<tr>
<td>Normal flat wing</td>
<td>245.83</td>
<td>891.82</td>
</tr>
<tr>
<td>Backside winglet</td>
<td>104.19</td>
<td>897.14</td>
</tr>
</tbody>
</table>

**Fig. 18.** Lift and Drag force according to wing tip type

**Fig. 19.** CL/CD ratio according to wing tip type

(1=Winglet  2=Normal flat wing  3= Backside winglet)

### V. CONCLUSIONS

In this study, Boeing 737 wing tip types are investigated in terms of the lift and drag force due to aerodynamic forces are the most critical parameters in the design step. Lift and drag forces on the three dimensional NACA 2415 Airfoil Wing is analyzed at different wing tip types.

It is seen that winglet is more effective on the lift force when the figure 18 is investigated. Winglet is better than normal flat wing nearly % 2 and is better than backside wing nearly % 1.5 in terms of the lift force.

Drag force is critical parameter for the fuel consumption. When the figure 19 is investigated, it is clearly seen that new design backside winglet is better than winglet nearly % 54 is better than normal flat wing % 57.

### REFERENCES


Biogeography-Based Optimization Algorithm for Designing of Planar Steel Frames

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Abstract—The optimization can be defined as a solution of problem under specific conditions to achieve a specific purpose. Optimization strategies commonly used for solving various problems have gained great importance in recent years especially in engineering. Evolving optimization methods over the years has many varieties such as shape optimization, topology optimization, size optimization etc. The latest trend of optimization methods is metaheuristics which are more useful with easy applicable to complex problems regarding to traditional optimization methods. So that metaheuristics have supplanted the traditional methods particularly in engineering by the time. In this study, a planar steel frame which is designed according to the requirements comprised by AISC-LRFD (American Institute of Steel Construction-Load and Resistance Factor Design) has been optimized by aid of biogeography-based optimization (BBO) algorithm.

Keywords—Planar Steel Frames, Optimum Design, Stochastic Search Techniques, Biogeography-Based Optimization, Metaheuristics.

I. INTRODUCTION

Many of design problem in engineering are too complex and multifaceted due to nonlinear characteristics. Stochastic optimization methods are compatible for dealing with nonlinear and complex design problems especially in civil engineering. Since stochastic optimization methods do not need any gradient information, these methods can be much more applicable especially in civil engineering problems.

In the literature, there are immense efficient studies on various metaheuristic optimization methods inspired by natural phenomena in structural engineering field. For instance, charged system search algorithm has been used in design optimization of skeletal structures [1], simulated annealing, evolution strategies, particle swarm optimizer, tabu search method, ant colony optimization, harmony search and simple genetic algorithm have been used in design of real size pin jointed structures [2], swarm intelligence based algorithms, harmony search method and charged system search have been practiced shape and topology optimization design of skeletal structures [3], firefly algorithm has been used to obtain the optimum design of retaining walls [4], harmony search algorithm has utilised optimum design of concrete cantilever retaining walls [5], genetic algorithm has applied multi-storey composite steel frames [6]. Among these, biogeography-based optimization (BBO) algorithm has outstanding popularity due to its capacity of rapidly converging to near-global optimum [7]. Biogeography is the study of the geographical distribution of biological organisms [8]. It is related to immigration, emigration and population of species etc. Robert MacArthur and Edward Wilson [9] have investigated on mathematical models of biogeography interest. They have focused on the distribution of species among at neighboring islands. Then, inspired by the science of biogeography Dan Simon presented a new computational intelligence algorithm, so-called biogeography-based optimization (BBO) algorithm [10]. There are some studies in different areas include the application of BBO; such as constrained optimization problems [11], best compromise solution of economic emission dispatch [12], optimal job scheduling in cloud computing [13], soft-sensor models [14], AC transmission system devices [15]. In structural engineering, BBO is also promisingly utilized in obtaining the optimum design of cost optimization of reinforced concrete cantilever retaining walls under seismic loading [16], optimization of spatial steel frames [17], optimal carbon dioxide emissions of the RC retaining wall design [18].

In this paper, optimum design of planar steel frames according to AISC-LRFD (American Institute of Steel Construction-Load and Resistance Factor Design) [19] is investigated by using BBO algorithm. Main purpose of this study is to find minimum design weight of a planar steel frame by selecting suitable steel sections taking into account of code requirements according to AISC-LRFD. Code specifications necessitate the consideration of a combined strength constraint with lateral torsional buckling for beam-column members. Furthermore displacement constraints as well as inter-storey drift restrictions of multi-storey frames are also included in the design formulation. Further constraints related with the constructability of a steel frame are also considered.

II. OPTIMUM DESIGN FORMULATION TO AISC-LRFD

The discrete optimum design problem of steel frames where the minimum weight is considered as the objective can be explained as follows:

Find a vector of integer values \( \mathbf{I} \) (Equation 1) representing the sequence numbers of steel sections assigned to \( N_o \) member groups

\[
\mathbf{I} = [I_1, I_2, \ldots, I_{N_o}] \tag{1}
\]

to minimize the weight \( \mathbf{W} \) of the frame.
\[ W = \sum_{i=1}^{N_i} \rho_i A_i \sum_{j=1}^{N_j} L_j \]

where \( A_i \) and \( \rho_i \) are the length and unit weight of the steel section adopted for member group \( i \), respectively, \( N_i \) is the total number of members in group \( i \), and \( L_i \) is the length of the member \( j \) which belongs to group \( i \).

The members subjected to

\[
\frac{(\delta_j - \delta_{j-1})}{h_j} \leq \delta_{\phi}, \quad j = 1, \ldots, ns
\]

\[
\delta_j \leq \delta_u, \quad i = 1, \ldots, nd
\]

\[
V_u \leq \phi V_n
\]

\[
\left( \frac{P_n}{\phi P_n} \right) + \left( \frac{8 M_{ax}}{9 \phi M_{ax}} \right) \leq 1.0 \quad \text{for } \frac{P_n}{\phi P_n} \geq 0.2
\]

\[
\left( \frac{P_n}{2 \phi P_n} \right) + \left( \frac{M_{ax}}{\phi M_{ax}} \right) \leq 1.0 \quad \text{for } \frac{P_n}{\phi P_n} \leq 0.2
\]

\[
B_{j_{pb}} \leq B_{j_{bc}} \quad j = 1, \ldots, nj
\]

\[
D_s \leq D_{s_{-1}} \quad s = 1, \ldots, nu
\]

\[
m_s \leq m_{s_{-1}}
\]

Equation (3) represents the inter-storey drift of the multi-storey frame. \( \delta_j \) and \( \delta_{j-1} \) are lateral deflections of two adjacent storey levels and \( h_j \) is the storey height. \( ns \) is the total number of storeys in the frame.

Equation (4) defines the displacement restrictions that may be required to include other than drift constraints such as mid-span deflections of beams. \( nd \) is the total number of restricted displacements in the frame. \( \delta_u \) is the allowable lateral displacement. The horizontal deflection of columns is limited due to unfactored imposed load and wind loads to height of column/300 in each storey of a building with more than one storey. \( \delta_u \) is the upper bound on the deflection of beams which is given as (span/300) if they carry plaster or other brittle finish.

Equation (5) represents the shear capacity check for beam-columns. \( \varphi \) is resistance factor in shear, \( V_n \) required shear strength, \( V_n \) is nominal shear strength.

Equation (6) defines the local capacity check for beam-columns. \( M_{ax} \) is nominal flexural strength, \( M_{ax} \) is applied moment, \( P_n \) is nominal axial strength, \( \vartheta \) is applied axial load, \( \varrho \) is resistance factor for columns if the axial force is in compression, \( \vartheta \) is resistance factor in bending. It is apparent that computation of compressive strength \( \vartheta P_n \) of a compression member requires its effective length.

Equation (7) is included in the design problem to ensure that the flange width of the beam (B) section at each beam-column connection at joint \( j \) should be less than or equal to the flange width of column section. \( nj \) represents the total number of joints in the frame.

Equations (8) and (9) are required to be included to make sure that the depth (D) and the mass per meter (m) of column section at storey \( s \) at each beam-column connection are less than or equal to width and mass of the column section at the lower storey \( s-1 \). \( nu \) is the total number of these constraints.

### III. BIOGEOGRAPHY-BASED OPTIMIZATION (BBO) ALGORITHM

The BBO algorithm is one of the recent additions to the metaheuristic algorithms, introduced by Dan Simon in 2008 [8]. The BBO algorithm was developed by simulating the theory of island biogeography, which describes the extinction and migration of a species between islands. In the BBO algorithm, the island term is defined as an isolated area for species. The two main indices, called the habitat suitability index (HSI) and suitability index variables (SIVs), control the extinction and migrations. The HSI describes the suitability of the habitats for life. Habitats with a high HSI provide good living conditions for the species, which are related to value of the objective function. These habitats have a low immigration rate and high emigration rate since they are already nearly saturated. Fig. 1 shows the relationship between species count, immigration rate and emigration rate [8]. In the figure, \( I \) and \( E \) represent the maximum immigration and emigration rates, respectively, \( \lambda \) and \( \mu \) are the immigration and the emigration rates, respectively, \( S_0 \) is the equilibrium number of species and \( S_{max} \) is the maximum species count.

![Fig. 1 Species model of a single habitat where \( \lambda \) is immigration rate and \( \mu \) is emigration rate](image)

The BBO algorithm consists of two main parts: migration and mutation. In the migration part, the new solution is generated by modifying the independent design variable of the old solution. The probability of the modification is related to the immigration rate of the solution. If an independent variable is to be modified, then the value of the independent design variable is determined using the roulette wheel selection method, which is related to the emigration probability. The emigration probability is calculated as follows [16]:

\[
P(x_j) = \frac{\mu_j}{\sum_{i=1}^{ps} \mu_i} \quad j = 1, \ldots, ps
\]

where \( ps \) is the population size.

Mutation is used to increase the number of species in the islands. If mutation occurs, the new solution is generated.
using a random search, as described in Equation (11). The mutation probability of each design is described in Equation (12).

\[ x_i = x^a_i + \text{rand}(0,1)(x^u_i - x^a_i) \quad i = 1, \ldots, ps \]  

\[ m(s) = m_{\text{max}} \left( 1 - \frac{P_i}{P_{\text{max}}} \right) \]  

where \( x^a_i \) and \( x^u_i \) are upper and lower bounds of the \( i \)th design variable \( x_i \), \( \text{rand}(0,1) \) is a random number between 0 and 1, \( m_{\text{max}} \) is the maximum mutation probability defined by the user, \( P_i \) is the number of species in the habitat, and \( P_{\text{max}} \) is the maximum number of species.

Each design is analyzed under the external loading and the design constraints given in Equations (3)–(9) are checked. If a candidate design does not satisfy the design constraints, its objective function value is penalized in accordance with constraint violations using Equation (13):

\[ f_{\text{cost},i} = f_{\text{cost}}(1 + C)^i \]  

where \( f_{\text{cost}} \) is the objective function value given by Equation (2), \( f_{\text{cost},i} \) is the penalized objective function value, \( C \) is the summation of constraint violations calculated using the constraint functions stated by Equations (3)–(9), and \( \epsilon \) is the penalty coefficient, which is taken as 2.0 in this study. In general form, constraint violations are calculated as:

\[ C_i = \begin{cases} 0 & g_i(x) \leq 0 \\ g_i(x) & g_i(x) > 0 \end{cases} \quad i = 1, \ldots, NC \]  

where \( g_i(x) \) is the \( i \)th constraint function, \( x \) is the vector of design variables, and \( NC \) is the number of constraint functions in the optimum design problem.

IV. DESIGN EXAMPLE

In present study, optimization of a six-storey, two-bay planar steel frame shown in Fig. 2 is considered as design example. The frame consists of 30 members that are collected in 8 groups as shown in the figure. The allowable inter-storey drift is 1.17cm while the lateral displacement of the top storey is limited to 7.17cm.

Furthermore, the wide-flange (W) profile list of ready sections is used to size the structural members. The material properties of steel are taken as follows: modulus of elasticity \( E = 208 \) GPa \((30,167.84 \text{ ksi})\) and yield stress \( F_y = 250 \) MPa \((36.26 \text{ ksi})\), and unit weight of the steel \( \rho = 7.85 \) ton/m³.

The investigated example includes minimum weight design of a planar steel frame structure. The optimum design to this frame with the BBO is sought by implementing the algorithm over a predefined number of iterations such as 20,000. In order to evaluate the accuracy of the final solution obtained with the BBO, the optimum solution is compared to those previously reported in the literature by some other robust metaheuristic algorithms, and the results are evaluated. The frame is formerly designed by three different optimum design algorithms that are based on three different metaheuristic algorithms such that cuckoo search algorithm, particle swarm optimizer and big bang-big crunch algorithm as reported in Ref. [20].

Due to the stochastic nature of the BBO, design problem is independently solved several times and the best result collected is used for comparison. The population size is set to 75, and the number of elites that specify how many of the best solutions to keep from one generation to the next is set to 2.0 for the design example. The mutation probability per solution per independent variable is selected as 0.01, as well. These parameter values are assigned as constant that are arbitrarily chosen within their recommended ranges by Simon [7, 8] based on the observed efficiency of the technique in different problem fields. It is obvious that best values of these parameters depend on the size of search space.

The section designations attained for each member group by BBO algorithm and by the others posted in the literature are tabulated in Table I. Besides, minimum frame weight located by the BBO algorithm is compared with the available results reported in the literature based on a cuckoo search optimization (CSO), a particle swarm optimizer (PSO), and a big bang-big crunch (BB-BC) algorithm [20]. Also, maximum constraint values for each algorithm are illustrated in this table. According to these results, the BBO algorithm locates an optimum design weight of 62.090kN, \((6331.44\text{ kg})\) which is lighter than the design weights obtained by the other techniques. The optimum design produced by BBO is 9.17, 15.94, and 16.51% lighter than those attained by CSO, PSO, and BB-BC, respectively.

Fig. 2 Six storey- two bay planar steel frame
It is noticed that in optimal design attained by BBO algorithm inter-storey as well as to ultimate strength constraints values are very close to their upper bounds while the top storey drift constraint is 5.321cm which is relatively less than its upper bound 7.17cm. This clearly indicates that strength ratio and inter-storey drift constraints dominate in the design. It is apparent from Table I that while biogeography-based optimization algorithm required more structural analysis than particle swarm and big bang-big crunch algorithms, it required less structural analysis than cuckoo search algorithm to reach the optimum design. It should be worthwhile to mention that the biogeography-based optimization algorithm used in this study is the standard one not the improved version.

### TABLE I

<table>
<thead>
<tr>
<th></th>
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<td>7 Beam</td>
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<tr>
<td>8 Beam</td>
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<table>
<thead>
<tr>
<th>Max. inter storey drift (cm)</th>
<th>1.16</th>
<th>0.77</th>
<th>0.78</th>
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<tr>
<td>Max. strength ratio</td>
<td>0.99</td>
<td>0.94</td>
<td>0.99</td>
<td>0.98</td>
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<tr>
<td>Max. top storey drift (cm)</td>
<td>5.32</td>
<td>4.42</td>
<td>4.33</td>
<td>4.65</td>
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<tr>
<td>Minimum weight. kg (kN)</td>
<td>666.54</td>
<td>6970.66</td>
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<td>7583.56</td>
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<tr>
<td>No. of structural analysis</td>
<td>13040</td>
<td>18000</td>
<td>6890</td>
<td>9250</td>
</tr>
</tbody>
</table>

The design history of BBO algorithm is illustrated in Fig. 3. It is apparent from the figure that BBO algorithm shows rapid convergence rate. Therefore, it can be concluded that BBO algorithm has relatively demonstrated best performance in yielding the optimum design of six-storey, two-bay planar steel frame, so far.

### V. CONCLUSIONS

The optimum design algorithm developed in this study is based on biogeography-based optimization (BBO) technique which selects the optimum W-section designations from W-sections table for the beams and columns of a planar steel frame such that design constraints described in AISC-LRFD are satisfied and the frame has the minimum weight. In view of the results obtained it is concluded that the BBO method is an efficient and robust technique that can successfully be used in optimum design of planar steel frames and determines lighter optimum solutions compare to cuckoo search, particle swarm and big bang-big crunch methods. In the optimum design of six-storey, two-bay planar steel frame, the optimum design weight obtained by the BBO approach is 9.17, 15.94, and 16.51% lighter than the one attained by the other three metaheuristic techniques. Furthermore, the BBO technique basically has only three parameter to be specified by a user which are the population size, the number of elites, and the mutation probability. This provides robustness to the algorithm compared to many other metaheuristic techniques that require pre-determination of more parameters.

### REFERENCES


Blade Number Effect on the Thrust, Torque and Power of Propeller

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Abstract—In this study, thrust, torque and power concepts are investigated according to different blade number. The computational fluid dynamic (CFD) analysis of three dimensional (3D) flow over propeller is used for this investigation. Power and torque concepts are the important parameter for the design of aircraft and airfoil. Thrust is also another critical parameter for the aircraft performance. A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade. Each propeller blade is a rotating airfoil, which produces thrust and drag. Thrust parameter is directly proportionate with blade number. If the blade number of propeller increase, thrust will increase. If the blade number of propeller increase, the produced torque by propeller and the needed power to drive propeller will also increase. In this study, blade number (2, 3 and 4 blades) effect on the thrust, torque and power is investigated.

Keywords—Propeller, Finite Element Analysis, Power, Thrust, Torque

I. INTRODUCTION

A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. Propeller dynamics, like those of aircraft wings, can be modelled by either or both Bernoulli's principle and Newton's third law [1]. Propellers are the most critical parts for the propulsion systems. In the literature, nearly all studies are focused on marine propellers. There are few studies exist about aero propellers.

Noh et al. [2] investigated different angle of attack values (25°, 35° and 45°) effect on aerofoil and flat shape louvers. The symmetrical 4 digit NACA aerofoil shape was used as louvers and it had 10 mm thickness. Solid Works Flow Simulation tool was used for CFD analysis. The results show that pressure drop is more widespread in flat louvers as compared to aerofoil louvers.

Hong and Dong [3] was presented a process for numerical analysis of radial circulation distribution of propeller blade. This process is based on the results of numerical simulation of the velocity field around propeller blades and in the wake. They observe a hump in the radial circulation from the traditional method because of computation errors. But, the direct method with CFD simulation can prevent from these errors.

A method to estimate full-scale propeller torque and thrust consisting of low-frequency and high-frequency components in waves by free-running model ship test was proposed by Ueno and Tsukada [4]. The method estimates full-scale fluctuating propeller torque and thrust in waves when analyzing wave component in the effective inflow velocity to propeller. This method also makes it possible to incorporate into free-running model ship tests any engine model simulating interaction between propeller torque and engine torque.

Driss et al. [5] applied an experimental validation and numerical simulation to study the turbulent flow around a small incurved Savonius wind rotor. For the analysis Solid Works flow simulation tool was used. Navier-Stokes equations and standard k-ε turbulence model were used. These equations were solved by a finite volume discretization method. To validate the numerical method, an experiment is performed with an open wind tunnel equipped by a small incurved Savonius wind rotor.

The effect of the ducted fan, which is located inside the ground effect region, is investigated experimentally according to the helicopter hovering concept by Doğru et al. [6]. For this investigation, the thrust of the ducted fan is measured using two different experimental methods, which are static pressure measurement system and spring method to calculate the thrust. The main objective of the study is to investigate the ducted fan effect on the elevation of a concept helicopter when the ducted fan is located in the ground effect region. As a result of this study, it appears that the lift force decreases, as expected.

There are three theories used in the design of propellers. They are: blade element, momentum and vortex theory. Most of today’s propellers are designed using blade element theory. In this study, a standard propeller and numerical calculation method is used for cases. The computational fluid dynamic (CFD) analysis is used for numerical calculations.
II. NUMERICAL STUDY

In the numerical study external flow type is used. In addition, “exclude cavities without flow conditions” and “exclude internal space” are selected since the present study is not interested in cavities or spaces.

Air is defined as fluid domain for the environment of the system as shown in Fig. 1. Also, Rotational domain is created as shown in Fig. 2. Naca 4412 aerofoil is used to obtain the propeller as shown in Fig. 3.

Fig. 1 Simulation domain

Fig. 2 Rotational domain

Initial conditions are defined as shown in Fig. 1. There is no velocity in the any direction because there is no crosswind. Temperature is assumed to be room temperature (20 °C) on the atmospheric pressure. This numerical study was performed at the 2500 RPM (261.71 rad/s). Rotational region is covered with the environmental pressure to simulate the real conditions after the boundary conditions are defined.

Fig. 3 Propeller aerofoil [7]

Pressure and velocity distribution is obtained from numerical study as shown in Fig. 4 and Fig. 5 respectively.
Velocity and pressure distribution is obtained from numerical study as shown in Fig. 6 and Fig. 7 respectively.

Fig. 8 Velocity (m/s) distribution of 4 blades propeller

Fig. 9 Pressure (Pa) distribution of 4 blades propeller

Velocity and pressure distribution is obtained from numerical study as shown in Fig. 8 and Fig. 9 respectively.

III. NUMERICAL STUDY RESULTS

In this study, Propeller thrust and torque values are calculated by means of Solid Works flow simulation analysis program.

Thrust and torque values are calculated from the analysis program for the 3 blades propeller as shown in Table 2.

<table>
<thead>
<tr>
<th>TABLE II. RESULTS OF 3 BLADES PROPELLER</th>
</tr>
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<tbody>
<tr>
<td>3 Blades</td>
</tr>
<tr>
<td>Thrust (N)</td>
</tr>
<tr>
<td>Torque (N*m)</td>
</tr>
<tr>
<td>Power (watt)</td>
</tr>
</tbody>
</table>

Thrust and torque value are calculated from the analysis program for the 4 blades propeller as shown in Table 3.

<table>
<thead>
<tr>
<th>TABLE III. RESULTS OF 4 BLADES PROPELLER</th>
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<tbody>
<tr>
<td>4 Blades</td>
</tr>
<tr>
<td>Thrust (N)</td>
</tr>
<tr>
<td>Torque (N*m)</td>
</tr>
<tr>
<td>Power (watt)</td>
</tr>
</tbody>
</table>

In this study, Propeller thrust and torque values are calculated by means of Solid Works flow simulation analysis program.

Thrust and torque values are calculated from the analysis program for the 2 blades propeller as shown in Table 1.

<table>
<thead>
<tr>
<th>TABLE I. RESULTS OF 2 BLADES PROPELLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Blades</td>
</tr>
<tr>
<td>Thrust (N)</td>
</tr>
<tr>
<td>Torque (N*m)</td>
</tr>
<tr>
<td>Power (watt)</td>
</tr>
</tbody>
</table>

Fig. 10 Torque results according to blade numbers

Fig. 11 Thrust results according to blade numbers
Torque values are shown in Fig. 10 according to blade number. Also, thrust values are shown in Fig. 11 according to blade number.

IV. CONCLUSIONS

Thrust, torque and power values of propeller, which have different blade numbers (2, 3 and 4 blades) are examined. In this study, three dimensional flow over propeller is used for CFD analysis. Velocity and pressure distribution are obtained according to boundary and flow conditions. Maximum tip velocity is obtained nearly 112.67 m/s for all propellers.

This numerical study shows that; torque value is increasing linearly with respect to blade number. But, thrust value does not increase linearly as torque value. This means that, power requirement is increasing non-linearly due to blade number.

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Generation of Digital Terrain Model From Unmanned Aerial Vehicle Image Data

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Abstract—Nowadays, Un-manned Aerial Vehicle (UAV) platforms are having a practical and beneficial data source for analysing of terrain, surveying, three dimensional (3D) surface modelling of structures and extraction of constructions faades. Low-cost platforms with rotary or fixed wing UAVs are capable of performing the multi view geometry and structure from motion with amateur cameras in autonomous mode by autopilot systems. For the purpose of UAV flights are gathering images from sky which becomes powerful technique for many applications such as change detection, deformation monitoring and forestry applications in medium scale study areas. Mostly procedure of gathering raw image data is easier than a traditional photogrammetric pipeline with an image blocks calculations. Generation of very dense point clouds are possible after image alignment and estimating of camera pose by structure from motion (SfM) algorithms. Processing of raw point clouds can result as high accurate Digital Surface Model (DSM), further to that analysis of digital terrain model, in the other words bare earth extraction can be done. This paper presents the latest developments of UAV image processing methods with computer vision for distinctive applications, surveying and 3D modeling issues for landslide area. Automated processing steps are mentioned for image processing, camera orientation, DTM generation and orthomosaic production stage.

Keywords—UAV, DSM, DTM, Point Cloud, Landslide

I. INTRODUCTION

In order to investigate the procedure for the generation of digital elevation models (DEM’s) or another calling digital terrain models (DTMs) with a high accurate using unmanned aerial vehicles, a survey via a multi-rotor aircraft was performed over a Taskent province of Konya in Turkey. In practise, there is a comprehensive surveying techniques used to create digital terrain models at different scales and with different standards. Geodetic surveying methods, for instance total stations, global navigation satellite systems (GNSS), terrestrial laser scanning (TLS), airborne laser scanning (ALS), mobile laser scanning (MLS) are very impressive for the production of DTMs with very low measurement uncertainties on limited areas [1]. Airborne and satellite-based imaging systems have the most effective advantage of providing measurements from sky or space that are not obstacle by terrain blocks and hills for acquiring high resolution topographical data. Lately, unmanned aerial vehicles (UAVs) (also called unmanned aircraft systems UAS) have showed clearly their ability for the rapid generation of DTMs over large areas (approx. 400 ha at single flight), where the use of traditional techniques is not possible way to comparison on economy and manpower [2]. It has also make an impression on the main DEM techniques due to its advantages of high data processing speed, low flying height, and convenient flying preparation in the field [3]. There are studies have shown that UAV production DTMs are possible to generate high accuracy with several centimetres on DTM [3], [4]. Measuring at high precision DTM of the ground surface is the main matter with most studies [5]. In this paper, we have presented the efficient and high accurate DTM generation work flow from UAV images pipeline. This investigation provides better understanding and clarifying the production of DTM for rapid process, low-cost and middle size area mapping functionality investigation of UAV data.

II. STUDY SITE

The study area nearby the town of Taskent, Konya, Turkey was chosen as the investigation (Fig. 1).

The main purpose of this site selection is deformation monitoring due to the occurrence of landslide on steep slope and forestry area for extraction of displacement studies. Taskent landslide occurs annually on heavy precipitation seasons [6]. However, some of the landslide region is heavy forestry. Taskent landslide valley is situated in the south part of Taskent town. Taskent province approximately located on middle of Taurus mountain chain. The catchment area approximately covers 40 ha. Some part of the study area contains dense vegetation and tree canopy.

For the purpose of monitoring surface displacements, spatial coordinate information of bare ground surface are crucial data under vegetation canopy. Thus, DTMs generations are being important from DSMs produced from UAV images.

III. DATA ACQUISITION FROM UAV

Camera sensor is performed for gathering images from UAV platform. UAV platform was choosed as multirotor and stabilized gimbal system acquisition the image without blurred [7]. The platform has an efficient flight time of 45 minutes with 1000mah Lipo battery and it has potential to increase functionality against low wind speed. Flight speed is 5 m/s. Flying height can be set from 50 m to 500 m, depending on desired resolution of images.

It has autonomous flight capabilities with OEM-GPS and IMU (Inertial Measurement Unit) for global positioning of itself and finding heads of the platform for planned
block corridor. Furthermore, an active stabilizing camera mount equipped with a daily use compact camera (Canon SX260HS) is mounted. UAV vibrations are eliminating with rubber ball damper kit. Rubber ball dampers designed using a very flexible material in order to ensure a significant reduction of vibrations for isolating camera mounts from the motor vibrations of the drone[8].

IV. Field Campaign

On the field study, site has three different morphological specification. Bare surface, forestry and rough surface properties are mainly attract the attention on landslide. The main idea on this study monitoring landslide free of morphological features, detecting the real displacements on bare surface ie. without vegetation and with 3 Dimensional (3D) movements on rough concave featured surfaces. Due to the lack of UAV images can generate only top view of features, it is not possible to generate under tree or high vegetated areas on bare ground. However, different interpolation techniques and filtering vegetation techniques are estimates the ground surface from raw point cloud, as it mentioned in this paper. The proposed methodology for generation DTM from raw images is showed as flowchart in Fig. 2.

A. UAV Flights

Three different part of sections data had been investigated for this project with UAV image data and point clouds (Fig. 3, 4). Flight plans are evaluated on Mission planner open source software [9].

Flight overlaps on side and forward side are calculated, optimised for best acquiring data for cover whole interested area without leave any gaps between image blocks. Ground sampling is depend on the flight height and slope feature of the surface. In our study average size was 0.05 m/pix and flying height for 3 flights 160 m averagely. In order to increase the level of detail of generated surface, flying altitude need to decrease, but the research area is located in valley, its risky for low altitude flight, so the low flight heights avoided for our project due to the crash risk, thus we need to optimise the flying height on this level. The UAV platform control had been chosen automatically for take off...
and landing. Pixhawk autopilot system used for this platform [10]. Copter platform requires flat surface on the ground for perpendicular take off and landing operations on the ground.

UAV platform camera system is non-calibrated and simple amateur system. Hence, unstable camera geometry necessitates either a temporary transportable calibration field or self-calibration during data processing [5]. Pix4D software has a library for calibration of cameras automatically matches the images for calibration parameters. After initial matching procedures (aligning images/blocks) and importing Ground control points (GCPs), it is able to optimize parameters with field calibration procedures. Initial and optimized parameters can be seen on (Table I).

**Table I**

<table>
<thead>
<tr>
<th>Initial Values</th>
<th>Focal Length</th>
<th>Principal Point x</th>
<th>Principal Point y</th>
<th>R1</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2</td>
<td>4.500 [mm]</td>
<td>3.099 [mm]</td>
<td>2.324 [mm]</td>
<td>-0.013</td>
</tr>
<tr>
<td>R3</td>
<td>4.500 [mm]</td>
<td>3.099 [mm]</td>
<td>2.324 [mm]</td>
<td>-0.013</td>
</tr>
<tr>
<td>T1</td>
<td>4.500 [mm]</td>
<td>3.099 [mm]</td>
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</tr>
<tr>
<td>T2</td>
<td>4.500 [mm]</td>
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<td>2.324 [mm]</td>
<td>-0.013</td>
</tr>
<tr>
<td>Optimized Values</td>
<td>Focal Length</td>
<td>Principal Point x</td>
<td>Principal Point y</td>
<td>R1</td>
</tr>
<tr>
<td>R2</td>
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B. Ground Measurements GNSS Surveys

DTM productions from different periods are able to compare, and create a Global datum in space, we use ground control points (GCPs) which is measured by real time kinematic GPS/GNSS. RTK-GNSS technique refers to a DGPS process where carrier-phase corrections are sent in real-time from a reference receiver at a known coordinate and height location to other rover receivers. To get the best in precision using GPS systems, RTK systems had been used in the field for acquiring real time high accurate coordinate. The measurement procedure completed with two GNSS receivers, for setting up on know base station and a rover. Both GNSS units locked onto satellites over 4, and also communicated between themselves via a radio link. The semi-permanent base station had been imported its position as a know coordinate on the Earth’s ground surface to around a 10 cm accuracy, and it needs to close survey area approximately under 5 km but the rover gets its position relative to the base to millimetre accuracy. By just setting up the rover unit on the GCP artificial points, these RTK systems can operate at the same time produce millimetre accuracy coordinate data that can be used for create very accurate basic surveying measurements (Coordinates components: North, East, Up). These control points which the geodetic data acquired by GNSS - RTK are used to address absolute orientation on processing step. These points are also checked the accuracy of the point cloud particularly that generated from UAV image collections [11], [12]. Root Mean Square Error (RMSE) is used to measure uncertainty values between point cloud surface coordinates and GNSS (true value) coordinates. The RMSE result shows the quality control check values of the dataset. This control procedure is fundamental for quality of the orientation of images and bundle block adjustment results.

\[
RMSE = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (e_i - \bar{e})^2} \tag{1}
\]

where \(e_i\) is observed values, \(\bar{e}\) is reference values and \(n\) is number of points.

V. Processing steps

Generated orthophoto covers about 31 ha of the study area. UAV image and GNSS-RTK measured GCPs are processed in state art of the commercial software Pix4D. The dataset (images, optional but recommended: images geolocation and GCPs) have to be obtained on the field before using Pix4Dmapper. Geolocation steps are done by open source software Mission planner. Exif values of the image are overwriting from the OEM-GNSS and tagging Ellipsoidal (Geographic) coordinates to the image properties. Image coordinates are estimated by time interval and interpolated from log file of autopilot system of UAV platform. A good dataset is required in order to automatically produce results with high quality and accuracy [13]. In order to take a good dataset, following steps have been finished:

- Designing the image acquisition plan (Mission Planner)
- Configuring the camera settings
- Geolocating images
- GCPs measurement before or after flight

In terms of to achieve high accuracy results, overlapping between images have to be acquired high triggering camera interval or very close corridors for side-laps. Therefore, the route of UAV platform plan has to be carefully designed to have sufficient image overlap. Notably, high detailed required GSD projects are depends on the flight altitudes. GSD value had calculated using by following equation [14],

\[
GSD = \frac{p}{c} \tag{2}
\]
where \( p \): CCD pixel size of camera, \( H \): flying height, \( c \): camera focal length

VI. NON-GROUND OBJECT FILTERING WITH FUSION

GroundFilter module from FUSION is designed to filter a cloud of LIDAR returns to identify those returns that lie on the probable ground surface (bare-earth points) [15]. It has capable of filtering any kind of point cloud file in .las file format or converted file format from ASCII standards. Most of the filtering algorithms have their own advantages and disadvantages, in this module does not produce a perfect set of ground returns in that it does not completely remove returns from large, flat or elevated surface such as building roofs. Mostly it is suitable for vegetated returns with the appropriate coefficients for the weight function and sufficient iterations. GroundFilter has shown that the default coefficients for the weight function produce good results in high-density point clouds (> 4 returns/sq m). The program could give a result with low-density point clouds but some training for parameter are needed to find best suited parameter values. Also, GroundFilter produces point sets for calculating vegetation heights. This module is also containing ground surface point sets stored LDA format. LDA formatted file is an indexed binary format that allows rapid random access to large datasets. Further models have been generated with other existed FUSION modules such as GridSurfaceCreate or TINSurfaceCreate utilities to produce a ground surface model.

![Fig. 5. Above ground height, red colors high and blue colors low height above ground](image)

**Fig. 5.** Above ground height, red colors high and blue colors low height above ground

FUSION software is running by command line. Filtering algorithm has been implemented linear prediction with an individual accuracy for each measurement of point sets and it works iteratively. Firstly, the surface is computed with equal weights for all points, or to be more precise, for all point height measurements. This surface runs in an averaging way between terrain points and vegetation points. The terrain points are more likely to have negative residuals, whereas the vegetation points are more likely to have small negative or positive residuals. These residuals are used to compute weights for each measurement [16].

![Fig. 6. Dense Point cloud, a) raw point cloud, b) filtered point cloud](image)

**Fig. 6.** Dense Point cloud, a) raw point cloud, b) filtered point cloud
VII. RESULTS

A. DTM Generation

DTM has modelled after ground points extracted from raw point clouds. Gridsurfacedcreate module of FUSION software was used for the surface generation with basic parameters. Over 8 million raw point set filtered and approximately 4 thousand bare ground points extracted. The cell elevation for the surface model is the average elevation of all points in a cell (1x1 m). The model cell size is the same as the intermediate surface cell size (specified by cellsize and smoothing is done depending on the /smooth:3x3 m and /median: 1x1 m switches. In general, the surface model produced by GroundFilter is coarse to be useful. It provides a quick check on the results of the bare-earth filtering as the resulting PLANS DTM file can be displayed for evaluation in the PDQ viewer. Thus further analysis had been done and the surface model created with DTM2ASC module. DTM2ASC converts data stored in the PLANS DTM format into ASCII raster files. Such files can be imported into SAGAGIS and Surfer software. Analytical hill-shade analysis for the presenting surface detail and smoothed surface features can be viewed and inspecting (Figure 9). Ground surface extracted models can be show by new map feature as above ground height. By this way, the canopy model analysis can be done (Figure 5). DTM resolution the average density of points of an irregular DTM, or the grid spacing of a regular DTM is one of the most issue for DTMs. These parameters should maintain a reasonable accuracy to describe the topographic surface using the minimum number of points [17] (Figure 3). Topographic or contour maps can present the quality of dense surface maps which include vegetation or non ground objects. In terms of the inspection of non filtered point cloud for terrain, contour maps are shows the deviations on the surface due to the non ground objects (Fig. 7).

Fig. 7 shows that profile view from part of DSM and DTM raster surface. Green lines of profile (Fig. 7), are DSM points and brown lines presents that generated surface from ground point of raster surface. It shows the quality of point cloud segmentation from raw point cloud data (Fig. 6). Most part of the DSM models are include vegetation from raw point cloud, thus need to extract from point cloud as proposed methodology mentioned in section VI. High dense and above ground filtration process showed that on Fig 9 approximately 40 m high trees detected on study site. For further analysis ie. landslide movement detection, raw point clouds can not be used without filtration of vegetation. Topographic mapping productions ie. contour, gradient and slope maps of study area can be generate after noise and non-ground objects points filtered from raw points. Fig. 10 shows the topographic contour map generated from filtered point cloud.

B. Orthophoto generation

Visualization of terrain with DSM and overlay orthophotos are improve the visualization of terrain in 3D models. Orthophotos are usually created using a bare earth elevation model and do not take into account occlusions. But elevation differences in elevation, eventually relief displacements are increasing on the steep edges for higher buildings or trees can be so large that they will obstruct the terrain and objects next to them. Thus, true orthophoto generation is substantial to cover terrain that matching image to the DSM. A true orthophoto is generating process to restore any occluded terrain while at the same time including as many terrain as possible in the surface model. True orthophotos are basically include all details on surface models. Generation of true orthophotos are commonly necessary for images of high detail or low altitude, and rough terrain. In this study mostly production of DTM are under investigation, however orthophoto generation had been done processing pipeline from Pix4D software (Fig. 10 b). Generated orthophoto quality is important for understanding level of terrain detail. The production of orthophoto ground sample distance (GSD) had 5 cm interval. It includes high detail of ground. Vegetation, rock surface, road lines etc. can bee seen from generated orthophoto. Further investigations are going to under estimate for landslide monitoring from DTM comparison and keypoint matched orthophoto by digital image processing algorithms. In this way, automatically change detections can be measured by 3D and 2D from UAV data.

VIII. CONCLUSIONS

UAV processing steps are highly automated and low cost features both makes this technique unique and stable on surveying applications. Image processing software and procedures are mostly rapid and user friendly. UAV is the newest technology for fast and accurate technique to generate DTM for low cost data collect and production system. The analysis of check points are showed that uncertainty (RMSE) of DTMs are enough for determine under decimetre level deformations on high density forestry landslide areas.
This accuracy levels are not only enough for mapping applications with UAV but also sufficient for medium scale deformation analysis and change detection applications by UAV platforms. For further detail few cm scale DTMs and orthophotos can be generate with high accuracy and very dense detail of levels with decrease flying height and improve georeferencing process with directional or in directional with increase GCPs number.

ACKNOWLEDGMENT
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USING NANOFIBERS IN FREQUENCY SELECTIVE SURFACES AS DIELECTRIC SUBSTRATE

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Abstract— Frequency selective surfaces (FSS) can allow and block electromagnetic (EM) waves depending on their shape and structure. In this study we demonstrate numerical analysis solutions of flexible micro strip band pass filter as FSS. Proposed design is produced from 50 micrometer thickness polycaprolactone (PCL) substrate which is electro spun nanofiber. The nanofiber flexible substrate is coated by nested two copper rings to constitute FSS. Designed unit cell showed band pass filter characteristic between 6.8 and 7.7 GHz. An array design of 3x3, consisting of same unit cells also displayed similar band pass filter characteristics at same frequencies.

Keywords— Frequency selective surfaces, nanofibers, microwave, Polycaprolactone, Dielectric substrate

I. INTRODUCTION

Frequency selective surfaces (FSS) can allow and block electromagnetic (EM) wave transfers depending on their shape and structure [1]. Generally, FSSs consist of unit cells in various geometries [2]. Based on shapes and sequences of conductors and holes the FSS are used as band pass filters, band stop filters and reflector antennas etc. at microwave (MW) frequencies [3-4].

EM wave passing or blocking criteria of an FSS is inferred from transmission and reflection coefficients. A transmission band of an FSS is determined as frequencies that show reflection coefficients show value of -3 dB and higher. That means more than half of the energy is being transferred through the FSS. Besides, desired reflection coefficients lower than -10 dB show the frequencies that the average reflected power drop is below 10% [4].

Nanofibers have diameters less than 1 µm [5]. Nanofibers are produced from metals, ceramics, natural and synthetic polymers [6]. Polymer materials can be spun to form a specific surface of nanofiber mats during their producing process [7].

In this study; we explore nanofiber mats as FSS and conduct their numerical analysis [8]. We proposed a design indicating band pass filter characteristic at microwave (MW) frequencies because of its micro-strip thickness.

For calculations, we used properties of polycaprolactone (C₆H₁₀O₆)n (PCL) nanofibers with 50 µm thickness. We have measured dielectric property (permittivity) of nanofiber mat experimentally with (Anritsu MS4624A- 9 GHz) network analyser and we found that εr=3.1 along the working frequencies. Conductive copper rings, whose conductivity is σ=5.8x10⁷ and 35 µm thickness, were used for constitution of FSS. For the purpose of design and modelling FSS simulation 3D simulation programs were used.

II. DESIGN

In this work, the proposed design of unit cells had 30 mm weight (W) and 30 mm length (L). Each unit cell had two copper ring foils. The radius of small ring (R1) is 6 mm and the big one (R2) is 10 mm. Each ring foil had 1 mm wideness (wl). The thickness of copper (t) was 0.035 mm and the thickness of PCL as substrate (d) was 0.050 mm. A top view of proposed unit cell for FSS and its sectional side view are shown in Fig. 1.

![Fig. 1 Proposed unit cell for FSS and its sectional side view](image-url)
In order to build FSS, the unit cells were repeated repeating in two directions (vertical and horizontal). An array of FSS consisted of 9 (3x3) unit cells. Therefore, the array structure had 90 mm of total size in each direction $W_A=L_A=90$ mm. The front view of (3x3) FSS array shown in Fig. 2.

![Fig. 2 The front view of (3x3) FSS array](image)

III. RESULTS

For numerical solution; designed structure excited electromagnetically from front and back side of the FSS since specify the response of EM waves. This study prepared at simulation medium with two port excitation. Each port excitation gives S parameter of the design ($S_{11}$, $S_{12}$, $S_{21}$, $S_{22}$). Reflection and transmission coefficients computed from these S parameters.

The calculated reflection and transmission coefficients of FSS are given in Fig. 3. The designed unit cell displayed band pass filter characteristics at frequencies between 6.8 and 7.7 GHz. These design and its characteristics showed that design can be used as FSS. As it can be seen in figure 3, transmission band exceeds the -3 dB (blue dashed line) and reflection band falls beneath -10 dB (black solid line).

Similar to the unit cell, the reflection and transmission coefficients of the (3x3) array works at the same frequencies as it can be seen in figure 4.

![Fig. 4 Calculated reflection and transmission coefficients of (3x3) array](image)

In this study a novel FSS design was proposed and simulated using PCL nanofibers as dielectric substrate material for FSSs. A single unit cell and an array of FSSs were tested using computational methods. The FSS structures designed and simulated as band pass surface and their numerical solutions were presented in this work. The increase in the number of unit cells in array will produce larger FSS surfaces. However the filtering property does not effected change and keeps allowing and disabling EM waves at same frequencies.

With this study, it is shown that nanofiber mats can be used as dielectric substrates at microwave frequencies. Therefore, it would produce novel devices and solutions for applications for today’s technology [6-9].

References


\textbf{T}_0 \text{ Extended Pseudo-Semi Metric Spaces}

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\textbf{Abstract—} In early papers \cite{4}, \cite{16}, and \cite{19}, there are several ways to generalize the usual \(T_0\)-axiom of topology to topological categories. In this paper, we characterize each of these various forms of \(T_0\) extended pseudo-semi metric spaces and investigate the relationships among them as well as compare each of \(T_0\) extended pseudo-semi metric spaces with the usual ones.

\textbf{Keywords—} Topological category, pseudo-semi metric spaces, products, \(T_0\) spaces.

\section{Introduction}

In 1906, Fréchet \cite{11} introduced the notion of metric spaces which play an important role in mathematics. There are numerous generalizations and procedures generalizing the notions of metric spaces by weakening or omitting some of its axioms. In 1931, Wilson \cite{3} introduced quasi-metric spaces (where the condition of symmetry is omitted) and further developed in \cite{3} and \cite{13} have a particular character and significance in the area of Quantum mechanics \cite{14} experimental psychology \cite{10}, biological studies \cite{18}, from those sciences in which measurement plays an essential role. In 1990, Adámek and Reiterman \cite{2} defined extended pseudo-metric spaces (where an pseudo-metric is allowed to attain the value infinity).

There are several ways to generalize the usual \(T_0\)-axiom of topology to topological categories \cite{4}, \cite{16}, and \cite{19} and the relationships among various forms of generalized \(T_0\)-axiom in topological categories have been investigated in \cite{5} and \cite{19}. One of the uses of \(T_0\) objects is to define various forms of Hausdorff objects and regular objects \cite{6}, \cite{7}, \cite{8}, and \cite{9} in arbitrary topological categories.

In this paper, we characterize each of various forms of \(T_0\) extended pseudo-semi metric spaces and compare each of \(T_0\) extended pseudo-semi metric spaces with the usual ones.

\section{Preliminaries}

Let \(\text{Set}\) denote the category of all sets and functions and \(\mathbf{E}\) be any category. Recall, in \cite{1}, \cite{12} or \cite{17}, that a functor \(U: \mathbf{E} \to \text{Set}\) is said to be topological, or that \(\mathbf{E}\) is a topological category over \(\text{Set}\), the category of sets, if \(U\) is concrete (i.e., faithful and amnestic (i.e., if \(U(f) \cong id\) and \(f\) is an isomorphism, then \(f = id\)), has small (i.e., set) fibers, and is such that every \(U\)-source has an initial lift or, equivalently, is such that each \(U\)-sink has a final lift.

Note that a topological functor \(U: \mathbf{E} \to \text{Set}\) has a left adjoint \(D\), the discrete functor, and \(U\) has a right adjoint, called the indiscrete functor. Recall, in \cite{1} or \cite{17}, that an object \(X \in \mathbf{E}\) is indiscrete if and only if every map \(U(Y) \to U(X)\) lifts to a map \(Y \to X\) for each object \(Y \in \mathbf{E}\) and an object \(X \in \mathbf{E}\) is discrete if and only if every map \(U(X) \to U(Y)\) lifts to map \(X \to Y\) for each object \(Y \in \mathbf{E}\).

Let \(B\) be a set and let \(B^2 \sqcup \Delta B^2\) be the wedge product of \(B^2\) \cite{4}, i.e., two disjoint copies of \(B^2\) identified along the diagonal, \(\Delta\). A point \((x, y)\) in \(B^2 \sqcup \Delta B^2\) will be denoted by \((x, y)_{1} (x, y)_{2}\) if it is in the first (resp. second) component of \(B^2 \sqcup \Delta B^2\).

Recall that the principal axis map \(A: B^2 \sqcup \Delta B^2 \to B^2\) is given by \(A ((x, y)_{1}) = (x, y, x)\) and \(A ((x, y)_{2}) = (x, x, y)\), and the fold map, \(\nabla : B^2 \sqcup \Delta B^2 \to B^2\) is given by \(\nabla ((x, y)) = (x, y)\) for \(i = 1, 2\) \cite{4}.

Let \((B^2 \sqcup \Delta B^2)^{j}\) be the final lift of the \(U\)-sink \(i_{1}, i_{2}: U(X^{2}) \to B^{2} \to B^2 \sqcup \Delta B^2\), where \(i_{1}\) and \(i_{2}\) are the canonical injection maps.

\textbf{Definition 2.1.} (cf. \cite{4}, \cite{5}, \cite{16}, \cite{19}). Let \(U: \mathbf{E} \to \text{Set}\) be topological, \(X\) an object in \(\mathbf{E}\) with \(U(X) = B\).

\begin{enumerate}
\item \(X\) is \(\overline{T_0}\) if the initial lift of the \(U\)-source \(\{ A : B^2 \sqcup \Delta B^2 \to U(X^{2}) = B^2 \}\) and \(\nabla : B^2 \sqcup \Delta B^2 \to UD(B^2) = B^2\) is discrete.
\item \(X\) is \(\overline{T_0^*}\) if the initial lift of the \(U\)-source \(\{id : B^2 \sqcup \Delta B^2 \to U(B^2) = B^2\}\) is discrete.
\item \(X\) is \(\overline{T_0}\) if \(X\) does not contain an indiscrete subspace with (at least) two points.
\end{enumerate}

\textbf{Remarks 2.2.} In general, for an arbitrary topological category, it is shown in \cite{5} that if \(X\) is \(\overline{T_0}\), then \(X\) is \(\overline{T_0^*}\) and there are no further implications between \(T_0\) and each of \(\overline{T_0}\) and \(\overline{T_0^*}\). In \(\text{Top}\), the category of topological spaces and continuous functions, by results proven in \cite{4}, \cite{5}, \cite{16}, \cite{19}
all of the $T_0$. $\overline{T_0}$ and $T_0^*$ are equivalent and reduce to the usual $T_0$.

Recall, in [15], that an extended pseudo-semi metric space is a pair $(X,d)$, where $X$ is a set and $d: X \times X \rightarrow [0,\infty]$ is a
function fulfills $d(x,x)=0$ for all $x$ in $X$ and $d(x,y)=d(y,x)$ for all $x,y$ in $X$.

A map $f:(X,d) \rightarrow (Y,e)$ between extended pseudo-semi metric spaces is said to be a non-expansive if it fulfills the property $e(f(x),f(y)) \leq d(x,y)$ for all $x,y$ in $X$.

The category of extended pseudo-semi metric spaces and non-expansive maps is denoted by $\text{psMet}$ [15].

Theorem 2.3. $\text{psMet}$ is a topological category over $\text{Set}$.
Proof. Define the forgetful functor $U: \text{psMet} \rightarrow \text{Set}$ by $U((X,d))=X$ and for a non-expansive map $f:(X,d) \rightarrow (Y,e)$ between extended pseudo-semi -metric spaces $U(f)=f: X \rightarrow Y$. It is clear that $U$ is concrete. Note that for any set $X$, the fiber of $X$, $U^{-1}(X)$ is isomorphic to the set of all extended pseudo-semi metrics on $X$ which means $U$ has small fibers. It remains to show that every $U$ - source has an initial lift. Let $(X,d)$, $i \in I$ be a class of extended pseudo-semi metric spaces and $f_i: \text{U}(X,d)_i \rightarrow X$, $i \in I$ be a class of functions. Define a extended pseudo-semi -metric $d$ on $X$ by:

$$d(a,b) = \sup_{i\in I} (d_i(f(a),f(b)))$$

for all $a,b \in X$. Note that $(X,d)$ is an extended pseudo-semi metric space and $\{f_i: (X,d)_i \rightarrow (X,d), \ i \in I\}$ is a set of non-expansive maps. Let $(Y,e_i)$ be any extended pseudo-semi metric space and for any function $h : Y \rightarrow X$, $h \circ f_i: (Y,e_i) \rightarrow (X,d)$, $i \in I$, be non-expansive maps. We need to show that $h: (Y,e) \rightarrow (X,d)$ is a non-expansive map. Note that for all $a,b \in Y$ and for all $i \in I$, $d_i(h(a),h(b)) \leq e(a,b)$ since $h \circ f_i: (Y,e_i) \rightarrow (X,d)$, $i \in I$, be non-expansive maps and consequently, $d(h(a),h(b)) = \sup_{i\in I} (d_i(h(a),h(b))) \leq e(a,b)$. This means that $h: (Y,e) \rightarrow (X,d)$ is a non-expansive map. Hence, $\text{psMet}$ is a topological category over $\text{Set}$.

2.4. Let $(X,d)$, $i \in I$ be a class of extended pseudo-semi metric spaces and $X$ be a nonempty set. A source $\{f_i: (X,d) \rightarrow (X,d), i \in I\}$ is initial in $\text{psMet}$ if and only if for all $a,b \in X$, $d(a,b) = \sup_{i\in I} (d_i(f(a),f(b)))$ [15].

2.5. Let $(X,d)$, $i \in I$ be a class of extended pseudo-semi metric spaces and $X$ be a nonempty set. A sink $\{f_i: (X,d) \rightarrow (X,d), i \in I\}$ is final in $\text{psMet}$ if and only if for all $a,b \in X$, $d(a,b) = \inf_{i\in I} (d_i(a_i,b_i))$ where $a_i, b_i$ in $X$ such that $f_i(a_i) = a$ and $f_i(b_i) = b$. This is a special case of [15].

2.6. The discrete extended pseudo-semi metric structure $d$ on $X$ is given by for all $a,b \in X$

$$d(a,b) = 0 \text{ if } a = b \text{ and } d(a,b) = \infty \text{ if } a \neq b [15].$$

2.7. The indiscrete extended pseudo-semi metric structure $d$ on $X$ is given by $d(a,b) = 0$ for all $a,b \in X [15].$

III. $\mathcal{T}_0$ EXTENDED PSEUDO-SEMI METRIC SPACES

Theorem 3.1. An extended pseudo-semi metric space $(X,d)$ is $\overline{T_0}$ if and only if $(X,d)$ is discrete.

Proof. Suppose, $(X,d)$ is $\overline{T_0}$ and $x,y \in B$. If $x = y$, then $d(x,y) = d(x,x) = 0$ since $d$ is an extended pseudo-semi metric on $X$. Suppose that $x \neq y$. Let $u=(x,y)$ and $v=(x,y)_2$. Let $\pi_i : X \rightarrow B$ be the projection maps, $i = 1,2,3$ and $d_{\text{dis}}$ be the discrete extended pseudo-semi metric structure on $X$. Note that $u$ and $v$ are distinct points of the wedge $X^2 \vee X^2$ and $d_{\text{dis}}(\pi_i(u),\pi_i(v)) = 0$, $d(\pi_i(u),\pi_i(v)) = d(x,y) = d(x,y) = d(\pi_{12}(u),\pi_{12}(v))$ since $d$ is an extended pseudo-semi metric on $X$. Since $(X,d)$ is $\overline{T_0}$ and $u \neq v$, it follows from Definition 2.1, 2.4, and 2.6 that $\infty = \sup\{d_{\text{dis}}(\pi_i(u),\pi_i(v)), d(\pi_{11}(u),\pi_{11}(v)), d(\pi_{21}(u),\pi_{21}(v)), d(\pi_{12}(u),\pi_{12}(v))\} = \sup\{0, d(x,y) = d(x,y)\} = d(x,y)$, and consequently, $d(x,y) = \infty$ if $x \neq y$. Hence, by 2.6, $d$ is a discrete extended pseudo-semi metric on $X$.

Conversely, suppose that $d$ is a discrete extended pseudo-semi metric on $X$. We will show that $(X,d)$ is $\overline{T_0}$. Let $d''$ be the product extended pseudo-semi metric structure on $X^2$, $d_{\text{dis}}$ be the discrete extended pseudo-semi metric structure on $X^2$ and $\overline{d}$ be the initial structure on the wedge $X^2 \vee \Delta X^2$ induced by the $U$-source $\{A : X^2 \vee \Delta X^2 \rightarrow U(X^0), d'(x) = x^3 \}$ and $\overline{d} : X^2 \vee \Delta X^2 \rightarrow U(X^2, d_{\text{dis}}) = X^2$. By Definition 2.1, we need to show that $\overline{d}$ is a discrete extended pseudo-semi metric on the wedge $X^2 \vee \Delta X^2$.

Let $u$ and $v$ be any points of the wedge $X^2 \vee \Delta X^2$. If $u = v$, then $\overline{d}(u,v) = 0$.

Suppose that $u \neq v$. If $\overline{d}(u) \neq \overline{d}(v)$, then $d_{\text{dis}}(\overline{d}(u),\overline{d}(v)) = \infty$ which implies that $\overline{d}(u,v) = \sup\{d_{\text{dis}}(\overline{d}(u),\overline{d}(v)), d(\pi_{11}(u),\pi_{11}(v)), d(\pi_{21}(u),\pi_{21}(v)), d(\pi_{12}(u),\pi_{12}(v))\} = \sup\{\infty, d(\pi_{11}(u),\pi_{11}(v)), d(\pi_{21}(u),\pi_{21}(v)), d(\pi_{12}(u),\pi_{12}(v))\} = \infty$. If $\overline{d}(u) = (x,y) = \overline{d}(v)$
for some \((x, y)\) in \(X^2\) with \(x \neq y\), then \(u\) and \(v\) have the form \((x, y)\) and \((y, x)\) for some \(x\) and \(y\) in \(X\).

If \(u = (x, y)\) and \(v = (x, y)\), then \(d(u, v) = \sup\{d_{dis}(\nabla(u), \nabla(v)), d(\pi_{11}(u), \pi_{11}(v)), d(\pi_{21}(u), \pi_{21}(v)) \} = \sup\{d_{dis}(x, y), 0\} = d(x, y)\) since \(x = y\).

Hence, by 2.6, \(\overline{d}\) is a discrete extended pseudo-semi metric on the wedge \(X^2 \setminus X^2\). Thus, \(\overline{d}\) is a discrete extended pseudo-semi metric on \(X\).

**Theorem 3.2.** All extended pseudo-semi metric spaces are \(T_0^+\).

**Proof.** Let \((X, d)\) be an extended pseudo-semi metric space. Let \(d^e\) be the product extended pseudo-semi metric structure on \(X^2\), \(d_{dis}\) be the discrete extended pseudo-semi metric structure on \(X^2\), and \(d_1\) be the final structure on the wedge \(X^2 \setminus X^2\) induced by \(U\)-sink \(i_1, i_2: U(X^2, d^e) \rightarrow \mathbb{X} \rightarrow X^2 \setminus X^2\), where \(i_1\) and \(i_2\) are the canonical injection maps, and \(\overline{d}\) be the initial structure on the wedge \(X^2 \setminus X^2\) induced by the \(U\)-source \(\{ id: X^2 \setminus X^2 \rightarrow U(X^2, d^e) \} = X^2 \setminus X^2\) and \(\overline{d} : X^2 \setminus X^2 \rightarrow U(X^2, d_{dis}) = X^2\), where \(id\) is the identity map. By Definition 2.1, we need to show that \(\overline{d}\) is a discrete extended pseudo-semi metric on the wedge \(X^2 \setminus X^2\).

Let \(u\) and \(v\) be any points of the wedge \(X^2 \setminus X^2\).

If \(u = v\), then \(\overline{d}(u, v) = 0\).

Suppose \(u \neq v\). If \(\nabla(u) \neq \nabla(v)\), then \(d_{dis}(\nabla(u), \nabla(v)) = \infty\) which implies that \(\overline{d}(u, v) = \sup\{d_{dis}(\nabla(u), \nabla(v)), d_{1}(u, v)\} = \sup\{\infty, d_{1}(u, v)\} = \infty\). If \(\nabla(u) = \nabla(v)\) for some \((x, y)\) in \(X^2\), then \(u\) and \(v\) have the form \((x, y)\) and \((y, x)\) for some \(x\) and \(y\) in \(X\).

If \(u = (x, y)\) and \(v = (x, y)\), then, by 2.4 and 2.5, \(\overline{d}(u, v) = \sup\{d_{dis}(\nabla(u), \nabla(v)), d_{1}(u, v)\} = \sup\{d_{dis}(x, y), 0\} = d_{1}(x, y) = d(x, y)\) since \(x = y\).

If \(u = (x, y)\) and \(v = (x, y)\), then, by 2.4 and 2.5, \(\overline{d}(u, v) = \sup\{d_{dis}(\nabla(u), \nabla(v)), d_{1}(u, v)\} = \sup\{d_{dis}(x, y), 0\} = d_{1}(x, y) = d(x, y)\) since \(x = y\).

Theorem 3.3. An extended pseudo-semi metric space \((X, d)\) is \(T_0^+\) if and only if \((X, d)\) is an extended semi-metric space.

**Proof.** Suppose that an extended pseudo-semi metric space \((X, d)\) is \(T_0^+\). We show that \((X, d)\) is an extended semi-metric space, i.e., for any \(x, y \in B\), if \(d(x, y) = 0\), then \(x = y\). Suppose that \(x \neq y\). Let \(A = \{x, y\}\) and \(d_A\) be the initial extended pseudo-semi metric structure on \(A\) induced by the inclusion map \(i: A \subset X\). Note that \(d_A(x, x) = d_A(y, y) = 0 = d_A(x, y)\) and \(d_A(x, x) = d(x, x) = 0 = d(y, y)\). Thus, \(d_A(x, y) = d_A(y, x)\). Thus, \((X, d)\) is an extended semi-metric space, it follows that \(x = y\), a contradiction. Hence, an extended semi-metric space \((X, d)\) cannot contain an indiscrete subspace with \(at least\) two points. Thus, by Definition 2.1, \((X, d)\) is \(T_0^+\).

**Remark 3.4.** In psMet, the category of extended pseudo-semi metric spaces and non-expansive maps, by Theorems 3.1-3.4, \(\overline{d}\) implies \(T_0^+\) implies \(T_0\) but the converse of each implication does not hold, in general. In Top, the category of topological spaces and cotinuous maps, by Remark 2.2, all of the \(T_0\), \(\overline{T_0}\) and \(T_0^+\) are equivalent and reduce to the usual \(T_0\). In general, for an arbitrary topological category, it is shown in [7] that if \(X = \overline{T_0}\), then \(X = T_0^+\) and there are no further implications between \(T_0^+\) and each of \(\overline{T_0}\) and \(T_0^+\).

**IV. Conclusions**

In this work, we have given the characterization of
each of the $T_0$, $\overline{T_0}$ and $T_0^*$ extended pseudo-semi metric spaces and showed that $\overline{T_0}$ implies $T_0^*$ but the converse of each implication does not hold, in general (Theorems 3.1-3.3 and Remark 3.5). On the other hand, in $\text{Top}$, the category of topological spaces and continuous functions, by results proven in [3], [13] and [18], all of the $T_0$, $\overline{T_0}$ and $T_0^*$ are equivalent and reduce to the usual $T_0$.

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T₀ Reflexive Spaces

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Abstract— In this paper, we characterize each of various forms of T₀ reflexive spaces and compare each of T₀ reflexive spaces with the usual ones.

Keywords— Topological category, reflexive spaces, ordered sets, T₀ spaces.

I. INTRODUCTION

Order theory is a branch of mathematics that studies various kinds of binary relations that capture the intuitive notion of a mathematical ordering. Orders appear everywhere – at least as far as mathematics and related areas, such as computer science, are concerned (see [10], [11], [16]–[18]).

There are several ways to generalize the usual T₀-axiom of topology to topological categories [2], [3], [12], [18], and the relationships among various forms of generalized T₀-axiom in topological categories have been investigated in [3], [18]. One of the uses of T₀ objects is to define various forms of Hausdorff objects [2], [4], [7]–[9] and the closed subobjects of a given object [2], [7], [8] of an arbitrary topological category which is used to generalize the usual regular and normal topological spaces to topological categories [5], [6].

In this paper, we characterize each of various forms of T₀ reflexive spaces and compare each of T₀ reflexive spaces with the usual ones.

II. PRELIMINARIES

Recall, in [1], [12] or [14], that a functor U : E → Set is said to be topological, or that E is a topological category over Set, the category of sets, if U is concrete (i.e., faithful and amnestic (i.e., if U(f) = id and f is an isomorphism, then f = id)), has small (i.e., set fibers, and is such that every U-source has an initial lift or, equivalently, is such that each U-sink has a final lift.

Note that a topological functor U : E → Set has a left adjoint D, the discrete functor, and U has a right adjoint, called the indiscrete functor. Recall, in [1] or [14], that an object X ∈ E is indiscrete iff every map U(Y) → U(X) lifts to a map Y → X for each object Y ∈ E and an object X ∈ E is discrete iff every map U(X) → U(Y) lifts to map X → Y for each object Y ∈ E.

Let B be a set and let B² ∨₃ B² be the wedge product of B² [2], i.e., two disjoint copies of B² identified along the diagonal, ∆. A point (x, y) ∈ B² ∨₃ B² will be denoted by (x, y)₁, (x, y)₂ if it is in the first (resp. the second) component of B² ∨₃ B².

Recall that the skewed axis map S : B² ∨₃ B² → B³ is given by S((x, y₁)) = (x, y, y) and S((x, y)₂) = (x, x, y), the principal axis map A : B² ∨₃ B² → B³ is given by A((x, y₁)) = (x, y, x) and A((x, y)₂) = (x, x, y), and the fold map, ∇ : B² ∨₃ B² → B² is given by ∇((x, y)) = (y, y) for i = 1, 2 [2].

Let (B² ∨₃ B²)ᵢ be the final lift of the U-sink i₁, i₂ : U(X²) = B² → B² ∨₃ B², where i₁ and i₂ are the canonical injection maps.

Definition 2.1. (cf. [2], [3], [13], [18]). Let U : E → Set be topological, X an object in E with U(X) = B.

1. X is T₀ if the initial lift of the U-source { A : B² ∨₃ B² → U(X²) = B²} and, ∇ : B² ∨₃ B² → UD(B²) = B² is discrete.

2. X is T₀" if the initial lift of the U-source { id : B² ∨₃ B² → U((B² ∨₃ B²)ᵢ) = B² ∨₃ B² and ∇ : B² ∨₃ B² → UD(B²) = B²} is discrete.

3. X is T₀ if X does not contain an indiscrete subspace with (at least) two points.

Remarks 2.2. In general, for an arbitrary topological category, it is shown in [3] that if X is T₀, then X is T₀" and there are no further implications between T₀ and each of T₀ and T₀". In Top, the category of topological spaces and continuous functions, by results proven in [3], [13], [18] all of the T₀, T₀ and T₀" are equivalent and reduce to the usual T₀.
The category $\text{RRel}$ of reflexive spaces (spatial graphs) has as objects the pairs $(B,R)$, where $B$ is a set and $R$ is reflexive relation on $B$, and as morphisms $(B,R)\to (B',R')$ those functions $f:B\to B'$ such that if $aRb$, then $f(a)Rf(b)$ for all $a,b\in B$. Note that $\text{RRel}$ is a topology categor over $\text{Set}$ [1], [10], [14].

2.3. A source $\{f:(B,R)\to (B',R), i\in I\}$ is initial in $\text{RRel}$ if for all $a,b\in B$, $aRb$ if and only if $f(a)Rf(b)$ for all $i\in I$ [1], [10], [14].

2.4. An epimorphism $f:(B,R)\to (B',R)$ is final in $\text{RRel}$ if for all $a,b\in B$, $aRb$ holds in $B'$ precisely when there exists $c,d\in B$, such that $cRd$ and $f(c)=a$ and $f(d)=b$ [1], [10], [14].

2.5. The discrete structure $R$ on $B$ is given by $aRb$ if and only if $a=b$ for all $a,b\in B$, i.e., $R=\Delta$ [1], [14].

2.6. The indiscrete structure $R$ on $B$ is given by $R=B^2$ [1], [14].

III. $T_0$ REFLEXIVE SPACES

**Theorem 3.1.** A reflexive space $(B,R)$ is $T_0$ if and only if $R$ is anti-symmetric.

**Proof.** Suppose $(B,R)$ is $T_0$ and for any $x,y\in B$, $xRy$ and $yRx$. We must show that $x=y$. Suppose that $x\neq y$. Let $u=(x,y)$ and $v=(y,x)$. Note that $\pi_1(A(u)R\pi_1(A(v)=xR\pi_2(A)\pi_2(A)\pi_1(A)\pi_1(A)\triangleleft \Delta 2\pi_1(A)$ and $\pi_2(A)\pi_2(A)\pi_1(A)\pi_1(A)\triangleleft \Delta 2\pi_2(A)\pi_2(A)$, which means $u=v=(x,y)$, a contradiction since $x\neq y$. Thus, $x=y$, i.e., $R$ is anti-symmetric.

Conversely, suppose that $R$ is anti-symmetric. We show that $(B,R)$ is $T_0$. Let $R'$ be the product relation structure on $B^4$ and $R_1$ be the initial structure on the wedge $B^2\vee\Delta B^2$ induced by the $U$-source $\{A:B^2\vee\Delta B^2\to U((B',R'))=B^2\vee\Delta B^2\}$ and $(\forall B':\vee\Delta B^2\to UD(B^2))=B^2$. By Definition 2.1, we need to show that $R$ is discrete, i.e., by 2.5, for any points $u$ and $v$ of the wedge $B^2\vee\Delta B^2$ if $uRv$, then $u=v$. If $uRv$, then $\pi_1(A(u)R\pi_1(A(v)=\pi_2(A)\pi_2(A)\pi_1(A)\pi_1(A)$ and $\pi_2(A)\pi_2(A)\pi_1(A)\pi_1(A)$, and $\forall (u)=\forall (v)$, and $u$ and $v$ have the form $((x,y),v)$ and $(x,y),v)$ for some $x$ and $y$ in $B$. If $u=(x,y),v$ and $v=(x,y),v$ , then $\pi_1((x,y))=(x,y),u$, $\pi_2((x,y))=(x,y),v$ for some $k=1$ or $2$ and consequently, $x=y$, i.e., $u=v$. If $u=(x,y),v$ and $v=(x,y),v$ , then $\pi_1((x,y))=(x,y),u$, $\pi_2((x,y))=(x,y),v$ for some $k=1$ or $2$ which implies $u$ and $v$ must lie in the component of the wedge $B^2\vee\Delta B^2$ which means $u=v$ for all $u$ and $v$. Thus, $R$ is discrete, i.e., by 2.1, $(B,R)$ is $T_0$.

**Theorem 3.2.** All reflexive spaces are $T_0$.

**Proof.** Let $(B,R)$ be a reflexive space, $(B^2\vee\Delta B^2)$ be the final lift of the $U$-sink $i_1,i_2:U(B^2,R'))=B^2\to B^2\vee\Delta B^2$, where $i_1$ and $i_2$ are the canonical injection maps and $R'$ is the product relation structure on $B^2$, and $R$ be the initial structure on the wedge $B^2\vee\Delta B^2$ induced by the $U$-source $\{i:R'=U((B^2\vee\Delta B^2))=B^2\vee\Delta B^2\}$ and $(\forall B^2\vee\Delta B^2\to UD(B^2))=B^2$ is discrete. By Definition 2.1, we have to show that $R$ is discrete, i.e., by 2.5, for any points $u$ and $v$ of the wedge $B^2\vee\Delta B^2$ if $uRv$, then $u=v$. Note that if $uRv$, then, in particular, $\forall (u)=(x,y)=\forall (v)$ for some $x,y\in B$, and consequently, $u$ and $v$ have the form $((x,y),v)$ and $((x,y),v)$. Then, by 2.4, if $u=(x,y),v$ and $v=(x,y),v$ , then $\pi_1((x,y),v)=(x,y),u$, $\pi_2((x,y),v)=(x,y),v$ for some $k=1$ or $2$ which implies $u$ and $v$ must lie in the component of the wedge $B^2\vee\Delta B^2$ which means $u=v$ for all $u$ and $v$. Thus, $R$ is discrete, i.e., by 2.1, $(B,R)$ is $T_0$.

**Theorem 3.3.** A reflexive space $(B,R)$ is $T_0$ if and only if $R$ is anti-symmetric.

**Proof.** Suppose that $(B,R)$ is $T_0$ and for any $x,y\in B$, $xRy$ and $yRx$. We must show that $x=y$. Suppose that $x\neq y$. Let $A=[x,y]$ and $R_A$ be the initial relation on $A$ induced by the inclusion map $i:A\subset B$. Since $R$ is reflexive and $x,y\in A$ , by 2.3, $xR_0y=yRx$ and $yR_0x=xRy$ , it follows from 2.6 that $R_A$ is indiscrete relation on $A$, a contradiction to $(B,R)$ is being a $T_0$ reflexive space. Hence, $x=y$ which shows that $R$ is anti-symmetric.

Conversely, suppose that $R$ is anti-symmetric and $A$ is any subset of $B$ with (at least) two points. Let $x,y\in A$ with $x\neq y$. If $R_A=A'$, the indiscrete reflexive relation on $A'$, then, in particular, $xR_Ay=yRx$ and $yR_Ax=xRy$. Since $R$ is anti-symmetric, it follows that $x=y$, a contradiction. Hence, a reflexive space $(B,R)$ can not contain an indiscrete subspace with (at least) two points. Thus, by Definition 2.1, $(B,R)$ is $T_0$.

**Theorem 3.4.** Let $(B,R)$ be a reflexive space. Then, the following are equivalent:

(i) $(B,R)$ is $T_0$.

(ii) $(B,R)$ is $T_0$.

(iii) $R$ is anti-symmetric.

**Proof.** It follows from Theorem 3.1 and Theorem 3.3.
Remark 3.5.

(1) In RRel, the category of reflexive spaces, by Theorem 3.4, \( \overline{T}_0 \) and \( T_0 \) are equivalent and implies \( T_0 \), but the converse implication does not hold, in general. In Top, the category of topological spaces, by Remark 2.2, all of the \( T_0 \), \( \overline{T}_0 \) and \( T_0^* \) are equivalent and reduce to the usual \( T_0 \). In general, for an arbitrary topological category, it is shown in [7] that if \( X \) is \( \overline{T}_0 \), then \( X \) is \( T_0^* \) and there are no further implications between \( T_0 \) and each of \( \overline{T}_0 \) and \( T_0^* \).

(2) Let for all \( i \in I \), \( (A_i, R_i) \) be reflexive spaces. Then, by Theorems 3.1-3.3, \( \prod_{i} A_i, R_i \) is a \( T_0 \), \( \overline{T}_0 \), and \( T_0^* \) reflexive space if and only if each \( (A_i, R_i) \) is a \( T_0 \), \( \overline{T}_0 \), and \( T_0^* \) reflexive space, respectively.

IV. CONCLUSIONS

In this work, we gave the characterization of each of the \( T_0 \), \( \overline{T}_0 \) and \( T_0^* \) reflexive spaces and showed that \( \overline{T}_0 \) and \( T_0 \) are equivalent and implies \( T_0 \), but the converse implication does not hold, in general. (Theorems 3.1-3.3 and Remark 3.5). On the other hand, in Top, the category of topological spaces and continuous functions, by results proven in [3], [13] and [18], all of the \( T_0 \), \( \overline{T}_0 \) and \( T_0^* \) are equivalent and reduce to the usual \( T_0 \).

ACKNOWLEDGMENT

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Removal of Congo red (anionic dye) from aqueous solutions by adsorption onto olive pomace

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Abstract— The removal of textile dyes from industrial effluents is one of the most serious environmental challenges in recent years. The aim of this study is to remove a toxic dyestuff, Congo Red (CR) from aqueous solutions by adsorption using olive pomace (OP) as a low-cost and eco-friendly adsorbent. The characterization of the adsorbent was carried out using conventional techniques like Scanning Electron Microscopy, Infrared Spectroscopy and Energy-dispersive X-ray Spectrometry.

Aqueous CR solutions with different initial concentrations (100-5000 mg L-1) were prepared using ultra high pure water obtained from Millipore UHP Water System. Each solution was shaken with known amounts of OP (0.05-0.25 g) in a 50 mL conical flask at 150 rpm speed. Batch experiments were carried out to observe the effect of various experimental parameters such as contact time, temperature, aqueous phase pH, initial CR concentration and also adsorbent dose. It was seen that the adsorption equilibrium was reached in 210 min. The percentage of adsorbed CR increased with the increase in OP amount in the system (Highest removal~88.2%). The process was slightly affected from the initial pH of the aqueous solution. Hence, pH was not adjusted in the experiments. The studies on the adsorption kinetic and isotherms were carried out and best fitting models were suggested. From the kinetic studies, it was seen that the adsorption obeyed to the pseudo-second order kinetic model ($R^2$=0.97). It was seen that the adsorption process best described by Freundlich isotherm model ($R^2$≥0.91). Thermodynamic studies showed that the process was exothermic in nature.

The results generated in this work can be used for determination of the optimum conditions for the removal of synthetic toxic dyes from aqueous solutions via adsorption using OP.

Keywords— Adsorption, synthetic dye, olive pomace, kinetics, characterization, isotherms.

I. INTRODUCTION

Today, more than 100,000 types of commercial dyes are used in the market. Nearly one million tons of synthetic dyes are produced per year and 10% of them are released into the environment and natural resources as waste [1]. The production is increasing every day to be able to meet the needs of growing population and this also results in the release of dye effluents. The disposal of these coloured substances poses one of industry’s major problems in waste water treatment. This is because the discharge of coloured wastes is not only damaging to the aesthetic nature of the receiving streams but also toxic to aquatic life and even carcinogenic or mutagenic in nature [2].

Congo red, the dye used in this study, is an anionic azo dye and is known as carcinogen causes blood clotting, respiratory problems and on ingestion, it produces gastrointestinal irritation with nausea, vomiting and diarrhea [3,4]. So, there is a critical need to treat the wastewaters containing this toxic synthetic dye before its discharge.

Today, removal of synthetic dyes is an important research topic, as government legislation concerning the release of contaminated effluent has become more stringent. Physical and chemical methods such as biological oxidation, adsorption, foam flotation, electrolysis, coagulation-flocculation, ozonation, oxidation, filtration, membrane separation, photo catalysis and electrochemical methods have been used for wastewater decolourisation [5,6].

Adsorption is one of the most efficient methods for the removal of synthetic dyes from wastewater. It provides an attractive treatment due to its simplicity, efficiency and low-cost. Especially using low-cost adsorbent further decreases the cost of the process. Several types of adsorbents from nature or among the waste materials have been tested for the purpose. Olive pomace (OP) has a great potential for the removal of toxic chemicals such as heavy metals and synthetic dyes. It is free of charge and readily available in the industry. In this study it was tested to be used for the removal of Congo red, an anionic dye [7].

II. MATERIALS AND METHODS

A. Materials

The olive pomace (OP) used in this study was supplied by one of the olive oil production plants in Turkey. Congo red (CR) with chemical formula, $C_{23}H_{28}N_6O_6S_2Na_2$ and molecular weight as 696.68 g mol$^{-1}$, was purchased from Merck. The molecular structure of the dye is illustrated in Fig. 1.

![Molecular structure of Congo red](image)

Fig.1. Molecular structure of Congo red.
B. Experimental Procedure

A constant temperature shaker bath (Jeio tech) was used during the experimental studies. A solution of CR with a concentration of 10g·L⁻¹ was prepared and all solutions were prepared using this stock solution. Initial concentration of dye solutions were adjusted between 100- and 5000 ppm. All solutions were prepared by using ultra high pure water obtained from Millipore UHP Water System. The effect of adsorbent dose was studied in the range of 0.05 - 0.25g. The two phases (10 mL aqueous phase vs. solid phase) were contacted in 50 mL erlenmeyer flasks by shaking at 150 rpm. After reaching the equilibrium, the mixture was centrifuged and the phases were clearly separated. Aqueous phase was analysed for CR amount before and after the experiment using an UV–Vis spectrophotometer (Shimadzu MINI-1240) and adsorption capacity of OP for CR was calculated using these values.

Kinetic studies were carried out using 0.1 g OP and 250 ppm CR solution. The samples were withdrawn at predetermined time intervals within five hours. The results presented that equilibrium was achieved in 3.5 hours. In addition effects of several adsorption parameters were investigated and availability of adsorption isotherms was studied.

III. RESULTS AND DISCUSSION

A. Characterization of adsorbent

The characterization of the adsorbent, OP was carried out by FT-IR and several types of functional groups were observed. The FT-IR spectra of the dye-free and dye-loaded OPs presented similarities showing that the adsorption process is physical. The intense of the peaks were observed to decrease with the dye loading. The SEM images clearly confirmed the presence of dye molecules on the OP.

C. Equilibrium studies and adsorption isotherms

The effect of initial CR concentration is shown in Fig. 5. According to the results, removal efficiency decreased with the increase in initial concentration of CR from 100 to 5000 mg·L⁻¹. This could be interpreted by the increase in number of competitive molecules with the increase in the initial dye concentration. The percentage of adsorbed CR increased with the increase in OP amount in the system (Highest removal ~ 88.2%). The process was slightly affected from the initial pH of the aqueous solution. Hence, pH was not adjusted in the experiments.

Well known adsorption isotherms such as Langmuir and Freundlich were used to interpret the equilibrium data. It was seen that the adsorption process best described by Freundlich isotherm model ($R^2\geq 0.91$).
Fig. 5. Effect of initial dye concentration and adsorbent dose on the adsorption of CR by OP.

Table 1. Thermodynamic parameters of the adsorption of CR onto OP.

<table>
<thead>
<tr>
<th>Thermodynamics Parameters for adsorption of CR onto OP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dye</td>
</tr>
<tr>
<td>CR</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

D. Thermodynamic studies and effect of temperature

The effect of temperature on the adsorption of CR on OP is shown in Fig. 9. The data indicates that increasing the temperature decreased the removal efficiency of the CR from aqueous solution. Thermodynamic studies showed that the process was exothermic in nature. The parameters calculated by thermodynamic data were shown in Table 1.

IV. CONCLUSIONS

In this study, olive pomace, a waste material of olive oil industry, has shown to be used for the removal of anionic dyes from aqueous solutions. The adsorption is highly dependent on various adsorption parameters such as adsorbent amount, contact time, pH and initial CR concentration. The adsorption capacity of OP for CR increased with the increase of the adsorbent mass. On the contrary, efficiency decreased with increasing the initial CR concentration. The change in pH was observed to have a slight influence on the adsorption of CR. The system reached equilibrium after 210 min. The kinetic data was indicating the applicability of the pseudo-second-order kinetic model. The equilibrium data was found to follow Freundlich isotherm model. Thermodynamic studies demonstrated that the process is exothermic in nature.

The results generated in this work can be used for determination of the optimum conditions for the removal of synthetic toxic dyes like CR from aqueous solutions via adsorption using OP.

REFERENCES

Comparison of Association Analysis Algorithms in SPSS Clementine and an Application

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\textbf{Abstract-} Data mining is the process of knowledge discovery in databases. One of the methods in data mining is association analysis. In this study we developed an application as association analysis by using SPSS Clementine data mining software. In the study, SPSS Clementine data mining Software Association analysis algorithms have been applied and compared. With the help of different association algorithms, new findings have been discovered for different market-basket analysis scenarios. We produce different association rules in each algorithm and this provides diversity for new customer strategies. This application of the study has been performed in a big shopping mall. The comparative results are reported and discussed.

\textbf{Keywords-} Data Mining, Market Basket Analysis, SPSS Clementine, Association Rules

\section{I. INTRODUCTION}

Data Mining is extraction process of important, new and useful information from large databases. Data mining is used to obtain meaningful patterns or rules and it is a widespread area of research.

In data mining “qualitative” and “quantitative” methods are used. In this context, in this research qualitative data are used for understanding and interpretation of the market basket data.

Data Mining is one of the most commonly used methods in the literature with the rules. Rules database and their relationship with each other is reviewed and with the help of the different algorithms, different results are obtained.

One of the application areas where the association rules are used is supermarket. Market basket analysis, called the relationship between the products purchased with the purpose of these studies is finding the association rules. In market basket analysis, customer’s buying habits are analyzed and products purchased together are determined.

Market basket analysis in supermarkets is carried out by using exchange of data chips for products that are purchased together. In this study, the different association algorithms are used and new findings were gained for different market basket analysis scenarios. Each algorithm includes different association rules and this provides variety. Relationship of different products with large scale of customers’ buying habits is determined. In this way, customers’ buying behaviors are analyzed and evaluated.

\section{II. LITERATURE SUMMARY}

When we look at the studies in the literature regarding the market basket analysis, Chen et al. (2005) uses the database for shopping records for a basket analysis application to determine the behavior. The information obtained from the analysis result of marketing, sales and operational strategies have been developed in this study [1]. Yang and Lai (2006), compared the performance of products based on knowledge decision on the promotion of online shopping behavior [2]. Umarani ve Punithavalli (2011) used different association rules algorithms on real-life data, such as retail sales and the market baskets [3]. Kamakura (2012), compared the traditional grocery cart with analysis and contrast sequential extension. Then, taking advantage of grocery shopping trips for the analysis of sequence data has suggested buying a picture frame [4]. Durdu (2012), used data mining tools and applications in the retail sector companies. He developed a customer relationship structure that is the basis for management activities [5].

Ceylan (2014), applied approach of association rules of data mining to reveal the relationship between the drugs [6]. Bayram (2014), made basket analysis for a company engaged in market research worldwide. He researched the relationship between traditional and modern channels [7]. Doğrul et al. (2015), researched accidents with association algorithms to extract beneficial information for human life. He used Apriori and GRI algorithms [8].

\section{III. MATERIALS AND METHOD}

In this study, the supermarket association rules with the application of internal market basket analysis, data mining is done.

\textbf{A. Market Basket Analysis and Association Rules}

Association Rules is a data mining approach. In this approach we discover interesting patterns of association marketing of large amounts of data. This provides benefits for decision-making and business management.
Association rules play an important role at information discovery from this database baskets [9]. One of the most common areas are the supermarket applications that use association rules. This application is known as the market basket analysis in the literature. Market basket analysis, which by revealing that the trend of the products sold with customer behavior, stock control, providing benefits to making the analysis, such as sales strategies [10]. Market basket analysis shows the distribution of customers from different perspectives. This information distribution planning, advertising design, sale - promotion, store layout and contributes decisions such as the granting of investment products [2].

Market Basket Analysis to clarify the relationship between the products sold in the analysis "support" and "confidence" as used two criteria. 'Rules of support measures' determines the rate at which it is repeated in all shopping for a relationship. The purchaser of the A product groups also revealed the possibility of buying the customers' B product groups [11].

B. The Algorithms Used for Association Analysis

A multi-algorithm that provides information from the data stack can be classified as sequential or parallel. Sequential algorithms are created and product set which contains logical expressions. Parallel algorithms allows the creation of large batches of product to parallelism [11].

1) GRI Algorithm: The Generalized Rule Induction (GRI) node discovers association rules in the data. For example, customers who purchase razors and aftershave lotion are also likely to purchase shaving cream. GRI extracts rules with the highest information content based on an index that takes both the generality (support) and accuracy (confidence) of rules into account. (Clementine Users Guide, 2007) [12].

2) Apriori Algorithm: The Apriori node extracts a set of rules from the data, pulling out the rules with the highest information content. Apriori offers five different methods of selecting rules and uses a sophisticated indexing scheme to process large datasets efficiently. For large problems, Apriori is generally faster to train than GRI; it has no arbitrary limit on the number of rules that can be retained, and it can handle rules with up to 32 preconditions. (Clementine Users Guide, 2007) [12].

3) CARMA Method: The CARMA model extracts a set of rules from the data without requiring you to specify In (predictor) or Out (target) fields. In contrast to Apriori and GRI, the CARMA node offers build settings for rule support (support for both antecedent and consequent) rather than just antecedent support [12].

IV. APPLICATION

In this study, we used SPSS Clementine for data mining application. The following procedure was applied:

i. Data collecting: Application is carried out in a supermarket we gathered data from the store. ii. Merge and cleaning: Differences found in the data collected in this step are fixed. Incorrect or analysis that may cause incorrect orientation of the data has been cleared. iii. Data conversion: This step was performed according to the model is transformed into data. Representations or identification of the data used by Apriori algorithm and the analysis model is changed.

After the necessary procedures carried out on the algorithm, we used GRI, Apriori and CARMA algorithm in the application of SPSS Clementine data mining. In SPSS Clementine program, model is solved with 3 types of algorithms. Association rules created in Figure 1, SPSS Clementine model is shown below. For modeling; 10 products are used. Figure 2 shows the 10 items assignment. We use 3 separate algorithms to reach the most accurate rules.
GRI, Apriori and CARMA algorithm the results are given in Figure 1, 2 and 3 below. We also show association rules for each algorithms in Table I, II and III respectively.

GRI algorithm results are presented in the following screen.

![GRI Model](image1)

**Fig.3. GRI Model**

GRI Algorithm based results are in Table I; a customer who buys product e, has 60% probability for buying product d. The possibility of coexistence of these products in shopping vouchers is 14.29%.

<table>
<thead>
<tr>
<th>Antecedent</th>
<th>Consequent</th>
<th>Support</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>e</td>
<td>d</td>
<td>14.29</td>
<td>60.0</td>
</tr>
<tr>
<td>d</td>
<td>g</td>
<td>17.14</td>
<td>66.67</td>
</tr>
<tr>
<td>e</td>
<td>f</td>
<td>14.29</td>
<td>60.0</td>
</tr>
<tr>
<td>d</td>
<td>h</td>
<td>17.14</td>
<td>66.67</td>
</tr>
<tr>
<td>d</td>
<td>j</td>
<td>17.14</td>
<td>66.67</td>
</tr>
</tbody>
</table>

Apriori Algorithm results seen in the following screen.

![Apriori Model](image2)

**Fig.4. Apriori Model**

Apriori Algorithm based results are in Table II; a customer who buys product d, has 66.667% probability for buying product g. The possibility of coexistence of these products in shopping vouchers is 18.182%.

<table>
<thead>
<tr>
<th>Antecedent</th>
<th>Consequent</th>
<th>Support</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>g</td>
<td>18.182</td>
<td>66.667</td>
</tr>
<tr>
<td>d</td>
<td>h</td>
<td>18.182</td>
<td>66.667</td>
</tr>
<tr>
<td>d</td>
<td>j</td>
<td>18.182</td>
<td>66.667</td>
</tr>
<tr>
<td>f</td>
<td>j</td>
<td>24.242</td>
<td>62.5</td>
</tr>
</tbody>
</table>

CARMA Algorithm results are seen in the following screen output:

![CARMA Model](image3)

**Fig.5. CARMA Model**

CARMA Algorithm based results are in Table III; a customer who buys product d, has 66.667% probability for buying product g. The possibility of coexistence of these products in shopping vouchers is 18.182%.

<table>
<thead>
<tr>
<th>Antecedent</th>
<th>Consequent</th>
<th>Support</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>d</td>
<td>g</td>
<td>18.182</td>
<td>66.667</td>
</tr>
<tr>
<td>d</td>
<td>h</td>
<td>18.182</td>
<td>66.667</td>
</tr>
<tr>
<td>d</td>
<td>j</td>
<td>18.182</td>
<td>66.667</td>
</tr>
</tbody>
</table>

If we look at the results in the table, showing the intersection of rules on the algorithm results are as follows:
TABLE IV
RESULTS OF INTERSECTION

<table>
<thead>
<tr>
<th>GRI</th>
<th>APRIORI</th>
<th>CARMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>e → d</td>
<td>e → d</td>
<td>-</td>
</tr>
<tr>
<td>d → g</td>
<td>d → g</td>
<td>-</td>
</tr>
<tr>
<td>e → f</td>
<td>e → f</td>
<td>-</td>
</tr>
<tr>
<td>d → h</td>
<td>d → h</td>
<td>-</td>
</tr>
<tr>
<td>d → j</td>
<td>d → j</td>
<td>-</td>
</tr>
<tr>
<td>-</td>
<td>f → j</td>
<td>f → j</td>
</tr>
</tbody>
</table>

The min confidence value above 60.0% probability, customers who purchase e product are buying d product. The min support value above 12.60% probability, products are available in shopping vouchers. The min confidence value above 60.0% probability, customers who purchase d product are buying h product. The min support value above 12.60% probability, products are available in shopping vouchers. The min confidence value above 60.0% probability, customers who purchase d product are buying j product. The min support value above 12.60% probability, products are available in shopping vouchers.

According to the findings of the study results, the result is changed for each algorithm. Common rules are out. In the later stages of operation, obtained 3 algorithm rules with new settlement arrangements will be developed.

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NARMA-L2 Controller Based on Online Support Vector Regression

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Abstract—In this study, a NARMA-L2 Controller based on online support vector regression is utilized to control a nonlinear continuously stirred tank reactor (CSTR) system. The main aim in study is to derive a SVR based NARMA-L2 controller via SVR NARX model of the system. For this purpose, firstly, SVR NARX model of the system is decomposed to its internal dynamics which can be represented via SVR-NARMA-L2 model, and then SVR-NARMA-L2 controller is designed via SVR-NARMA-L2 model of the system. The performance evaluation of the controller has been executed on a continuously stirred tank reactor (CSTR) and the results show that the NARMA controller together with NARMA model attain successful tracking performance with small modeling, transient-state and steady state errors.

Keywords—NARMA-L2 Model - NARMA-L2 Controller - Support Vector Regression - SVR-NARMA-L2 Controller - System Identification

I. INTRODUCTION

Nonlinearity is a significant feature of physical systems which complicates control design and degrades performance. The system model structures which enable to extricate the control signal from nonlinear inner dynamics of system model are very useful to derive model based controllers. NARMA-L2 controller, introduced by Narendra and Mukhopadhyay [2], is one of the most effective neural network controller architectures for nonlinear systems [1]. Basically, in NARMA-L2 model, the nonlinear system model can be represented via two subnetworks where the control signal is extricated from nonlinear dynamics of the system model via Taylor Expansion of the system model [1], [3], [4]. Thus, the NARMA-L2 model of the system can be easily converted to obtain the control signal utilized to compel system output to reference signal and NARMA-L2 controller is directly derived via NARMA-L2 model of the system. The lack of need for an extra network topology to design or train controller as in model reference adaptive control is an important advantage of the NARMA-L2 controller. In technical literature, there are various studies where artificial neural network (ANN) based NARMA-L2 controllers have been successfully used to control nonlinear systems [2], [3], [4], [5], [6], [7]. ANN based NARMA-L2 controllers suffer from modeling inaccuracies since the network topologies which are trained with back propagation algorithm (as in ANN and ANFIS) may get stuck at local minima resulting from their non-convex objective functions and system model is only obtained locally [1]. Therefore, SVM-based controller structures have been frequently deployed to derive model based adjustment mechanisms instead of ANN and ANFIS in recent studies [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22]. The NARMA controller includes two submodels which are independent from current control signal applied to the system. The parameters of these submodels in NARMA based on ANN can be easily adjusted without explicit information of the exact outputs of these submodels since backpropagation algorithm and chain rule enable to drive update rules for each parameter of the submodels. To obtain the optimum mapping function in SVR, the input-output training pairs must be available, however outputs of NARMA submodels are not known a priori, so estimating NARMA model with SVR is a hard task [1]. This problem was overcome by deriving the NARX model of the system first, and then obtaining NARMA submodels via NARX model of the system in [1]. In this study, an adaptive NARMA-L2 controller based on SVR previously proposed in [1] is deployed to control the CSTR system. The paper is organized as follows: Section II briefly describes online ε-Support Vector Regression. The basic principles of SVR based-NARMA-L2 model and controller are explained in Section III. In section IV, tracking performance evaluation of the controller has been examined on nonlinear CSTR system. The paper ends with a brief conclusion in Section V.

II. ONLINE ε-SUPPORT VECTOR REGRESSION

Consider a training data set:

$$T = \{x_i, y_i\}_{i=1}^{N} \quad x_i \in \mathbb{X} \subseteq \mathbb{R}^n, \ y_i \in \mathbb{R}$$

(1)

where \(x_i\) is the \(i^{th}\) input data and \(y_i\) is the corresponding output value, \(N\) is the size of the training data and \(n\) is the dimension of the input space. The relationship among training data set in (1) can be represented via SVR model in (2):

$$\hat{y}(x) = \sum_{i=1}^{N} \lambda_i K(x, x) + b$$ \quad \(\lambda_i = \beta_i - \beta_i^*\)  \quad (2)

where \(\lambda_i\) is the ith Lagrange multiplier; \(K(x, x)\) is the corresponding kernel value of the ith input sample and \(b\) is the bias term [19]. The parameters of the regression function
in (2) are obtained via the following optimization problem:

\[
D = \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} (\beta_i - \beta_j^*) (\beta_j - \beta_j^*) K_{ij} + \varepsilon \sum_{i=1}^{N} (\beta_i + \beta_j^*) - y_i \sum_{i=1}^{N} (\beta_i - \beta_j^*)
\]

subject to

\[
0 \leq \beta_i \leq C, \quad 0 \leq \beta_j^* \leq C, \quad \sum_{i=1}^{N} (\beta_i - \beta_j^*) = 0, \quad i = 1, 2, \ldots, N
\]

where \(K_{ij} = \Phi(x_i)^T \Phi(x_j)\) is the kernel value which represents the similarity among the \(x_i\) and \(x_j\) training samples. The training samples are separated into three main subsets depending on their Lagrange and margin values as:

- Error support vectors (E), support vectors (S) and remaining samples (R) [23].

\[
\begin{align*}
E & = \{i \mid |\lambda_i| = C, |h(x_i)| \geq \varepsilon \} \\
S & = \{i \mid 0 \leq |\lambda_i| < C, |h(x_i)| = \varepsilon \} \\
R & = \{i \mid |\lambda_i| = 0, |h(x_i)| \leq \varepsilon \}
\end{align*}
\]

In the incremental online SVR algorithm, when a new training data \(x_c\) is received, its corresponding \(\lambda_c\) value is initially set to zero, which is later updated to \(\Delta \lambda_c\) [19]. Then, the largest possible change \(\Delta \lambda_c\) is calculated while at the same time keeping the system at the equilibrium state with respect to the new KKT conditions [19]. Depending on \(\Delta \lambda_c\), the bias and the Lagrange multipliers of the samples in support set (S) are adjusted. Detailed information related to recursive algorithm can be achieved via [23], [24], [25].

III. NARMA Controller based on Online SVR

A. Controller Design

NARMA-L2 model depicted in Fig. 1(b) can be deployed to identify the nonlinear dynamics of a system in a neighborhood of the equilibrium state [2]. The output of the NARMA-L2 model is given as follows:

\[
\hat{y}_{NARMA} = \hat{f}_n + \hat{g}_n u_n
\]

where \(\hat{f}_n = F_n(x_n)\) and \(\hat{g}_n = G_n(x_n)\) denote the submodels computed by some numerical or intelligent estimator and \(x_n = [u_{n-1} \cdots u_{n-\alpha} \cdots y_{n-n_y+1}]^T\) stands for the current input feature vector of the model where \(n_\alpha\) and \(n_y\) emblematise the number of the past control inputs and system outputs included in the feature vector, \(d\) indicates the relative degree [1]. The main supremacy of NARMA-L2 model is that the control signal \(u_n\) can be easily computed via \(\hat{f}_n = F_n(x_n)\) and \(\hat{g}_n = G_n(x_n)\) submodels by substituting \(r_{n+1}\) in place of \(y_{n+1}\) as follows:

\[
u_n \triangleq \frac{r_{n+1} - \hat{f}_n}{\hat{g}_n}
\]

since it is aimed to compel system to reference signal in closed-loop control [1], [5], [23], [24]. In NN based NARMA-L2 models, the adjustment rules for the weights of the \(F_n(.)\) and \(G_n(.)\) submodels can be easily derived via backpropagation algorithm and chain rule without requiring to know exactly the output of \(F_n(.)\) and \(G_n(.)\) submodels. Since the greatest difficulty of SVR based modelling is the necessity of input-output data pairs and the outputs of \(F_n(.)\) and \(G_n(.)\) are not known exactly, it is difficult to design SVR submodels for \(F_n(.)\) and \(G_n(.)\) separately [1]. Therefore, it has been aimed to derive the parameters of SVR\textsubscript{NARMA}\textsubscript{L2} model via the parameters of the previously obtained SVR\textsubscript{NARX} model of a system as in Fig. 1. Therefore, SVR\textsubscript{NARMA}\textsubscript{L2} which we called as “main model” should be divided to submodels as in Fig. 1(b). Let us assume that the regression function for SVR\textsubscript{NARX} model of the system depicted in Fig. 1(a) at time step \((n-1)\) is given as

\[
\hat{y}_{NARX_n} = \sum_{i=1}^{N} \beta_i K(x_i, x_c) + b_{\beta}
\]

and the corresponding regression functions for \(F_{n-1}(x_{n-1})\) and \(G_{n-1}(x_{n-1})\) are as follows:

\[
\begin{align*}
F_{n-1}(x_{n-1}) &= \sum_{i=1}^{N} \alpha_i K(x_i, x_{n-1}) + b_f \\
G_{n-1}(x_{n-1}) &= \sum_{i=1}^{N} \theta_i K(x_i, x_{n-1}) + b_g
\end{align*}
\]

Thus, output of the SVR\textsubscript{NARMA}\textsubscript{L2} model can be acquired as:

\[
\hat{y}_{NARMA_n} = F_{n-1}(x_{n-1}) + G_{n-1}(x_{n-1}) u_{n-1} = \sum_{i=1}^{N} \left[ \alpha_i + \theta_i u_{n-1} \right] K(x_i, x_{n-1}) + b_f + b_g u_{n-1}
\]
In order to attain a relation between SVR$_{NARMA-L2}$ and SVR$_{NARX}$, (8) and (10) can be equalized as follows:

$$\hat{y}_{NARX_n} \equiv \hat{y}_{NARX_n}$$

$$\sum_{i=1}^{N} \beta_i K(x_i, x_{n-1}) + b_\beta = \sum_{i=1}^{N} \left[ \alpha_i + \theta_i u_{n-1} \right] K(x_i, x_{n-1}) + b_f + b_g u_{n-1}$$

$$\beta_i = \alpha_i + \theta_i u_{n-1}, \ b_\beta = b_f + b_g u_{n-1}$$

The following assumption has been proposed to utilize this relation effectively and to approximate the parameters of the submodels by this approach[1].

**Assumption:** Let us consider that the following relations exist between the parameters of the submodels:

$$\alpha_i = \mu_1(.) \theta_i, \ b_f = \mu_2(.) b_g$$

Utilizing (17) and (13), the bias and the lagrange multipliers of the SVR$_{NARMA-L2}$ submodels $F_{n-1}(x_{n-1})$ and $G_{n-1}(x_{n-1})$ are obtained with respect to parameters of SVR$_{NARX}$ model as follows for the given values of $\mu_1(.)$ and $\mu_2(.)$:

$$\theta_i = \frac{\beta_i}{\mu_1(.) + u_{n-1}}, \ \alpha_i = \mu_1(.) \theta_i$$

$$b_g = \frac{b_\beta}{\mu_2(.) + u_{n-1}}, \ b_f = \mu_2(.) b_g$$

As mentioned before, the outputs of the submodels can be computed depending on the model parameters adjusted at the previous step (n-1) since the model parameters of $F_n(.)$ and $G_n(.)$ are not known at time step n. Therefore, the output of the submodels at prediction phase can be expressed as follows:

$$\hat{f}_n \equiv F_{n-1}(x_{n-1}), \ \hat{g}_n \equiv G_{n-1}(x_n)$$

where subscript “—” in (15) indicates that the models obtained in the previous time step n-1 are updated with the current state vector $x_n$ to obtain $\hat{f}_n$ and $\hat{g}_n$ [1]. Similarly, “+” in $\hat{f}_n^+$ and $\hat{g}_n^+$ indicate that the model trained in current step (n) has been deployed together with the current state vector $x_n$ as follows [1]:

$$\hat{f}_n^+ \equiv F_n(x_n), \ \hat{g}_n^+ \equiv G_n(x_n)$$

Thus, the control signal ($u_n$) produced by SVR$_{NARMA-L2}$ controller can be given as:

$$u_n \equiv r_{n+1} - \hat{f}_n^-$$

where $\hat{f}_n^- = F_n(x_n)$ and $\hat{g}_n^- = G_n(x_n)$ and $x_n = [u_{n-1} \cdots u_{n-n} \cdots y_{n} \cdots y_{n-n+1}]^T$. In a nutshell, SVR$_{NARMA-L2}$ controller can be derived without knowing the output of the submodels $F_n(.)$ and $G_n(.)$ separately. The structure of the proposed controller is depicted in Fig. 2 where $y_{n+1}$ is the output of the system, $\hat{y}_{n+1}$ is the estimated system output, $r_{n+1}$ indicates the reference signal and $u_n$ is the control signal produced by the controller.

**B. Adaptive Predictive SVR$_{NARMA-L2}$ Controller with Adaptive Filter**

NARMA controller generally produces a control signal with more oscillation and chattering compared to other controllers such as MRAC, MPC etc. [5]. Therefore, the unmodeled high frequency dynamics of the system can be excited in the case that the high frequency components of the signal are not filtered. For this purpose, the control signal can be filtered in order to reduce chattering and oscillation in control signal [5]. Therefore, the following first order adaptive low pass filter with an adjustable parameter is utilized

$$H(z) = \frac{u_{f_n}}{u_{c_n}} = \frac{q_{0_n}}{1 + (1 - q_{0_n})z^{-1}}$$

where $1 - q_0$, $q_0$ are “feed-backward” and “feed-forward” coefficients of the filter respectively [1]. The closed-loop tracking performance of the controller directly hinges on the decomposition parameters ($\mu_{j}(.)$, $j \in \{1, 2\}$) utilized to obtain SVR$_{NARMA-L2}$ submodels as well as the filter parameter ($q_0$). A predictive structure which conceives the K-step ahead future behaviour of controlled system has been deployed to adjust both $\mu_{j}(.)$, $j \in \{1, 2\}$ and $q_0$ parameters effectively as in Fig. 3. The objective function in (19) is used to adjust $\mu_{j}(.)$, $j \in \{1, 2\}$ and $q_0$ parameters via Levenberg-Marquard algorithm [25]

$$E(\theta) = \frac{1}{2} \sum_{k=1}^{K} \epsilon_{n+k}^2 + \frac{1}{2} \lambda [u_n - u_{n-1}]^2$$

where $\epsilon_{n+k} = r_{n+k} - \hat{y}_{n+k}$. The adjustable parameters can be optimized as follows:

$$\begin{bmatrix} \mu_{1_{new}} \\
\mu_{2_{new}} \\
q_{0_{new}} \end{bmatrix} = \begin{bmatrix} \mu_{1_{old}} \\
\mu_{2_{old}} \\
q_{0_{old}} \end{bmatrix} + \begin{bmatrix} J^T \end{bmatrix} \begin{bmatrix} J \end{bmatrix}^{-1} J^T \epsilon$$

where

$$J = \begin{bmatrix} \frac{\partial y_{n+k+1}}{\partial u_{f_n}} \\
\vdots \\
\frac{\partial y_{n+k}}{\partial u_{f_n}} \end{bmatrix} q_{0_n - \frac{b}{g_n}} - q_{0_n - \frac{b_n}{g_n}} (u_n - u_{f_n - 1})$$

The components of the system Jacobian matrix $J_m$ are given as:

$$\frac{\partial y_{n+k}}{\partial u_n} \approx \frac{\partial f_n(c_{n+k})}{\partial d_{n+k,j}} \frac{\partial d_{n+k,j}}{\partial u_n} + \frac{\partial g_n(c_{n+k})}{\partial d_{n+k,j}} \frac{\partial d_{n+k,j}}{\partial u_n}$$

$$\frac{\partial f_n(c_{n+k})}{\partial d_{n+k,j}} = -\frac{1}{2 \sigma^2} \sum_{j \in SV} \alpha_j \exp\left(\frac{-d_{n+k,j}}{2 \sigma^2}\right)$$

$$\frac{\partial g_n(c_{n+k})}{\partial d_{n+k,j}} = -\frac{1}{2 \sigma^2} \sum_{j \in SV} \theta_j \exp\left(\frac{-d_{n+k,j}}{2 \sigma^2}\right)$$

and $\frac{\partial d_{n+k,j}}{\partial u_n}$ is detailed in [1].
IV. SIMULATION RESULTS

The performance evaluation of the controller has been realized on a continuously stirred tank reactor system (CSTR). CSTR is a type of chemical reactor where isothermal, liquid-phase, successive multicomponent chemical reactions can be uniformly realised [29], [30], [31]. Kravaris and Palanki [29] expressed the dynamics of the system as follows:

\[
\begin{align*}
\dot{x}_1(t) &= 1 - x_1(t) - Da_1 x_1(t) + Da_2 x_2^2(t) \\
\dot{x}_2(t) &= -x_2(t) + Da_1 x_1(t) - Da_2 x_2^2(t) - Da_3 d_2 x_2^2(t) + u(t) \\
\dot{x}_3(t) &= -x_3(t) + Da_3 d_2(t) x_2^2(t)
\end{align*}
\]

(24)

where \( x_1(t), x_2(t) \) and \( x_3(t) \) are states obtained from the concentrations of reactant A, middle reactant B and product.
Fig. 4. System Output (a), Control Signal (b), number of support vectors (c), adaptive controller (d,e) and filter parameters (f).

Fig. 5. System Output (a), Control Signal (b), number of support vectors (c), adaptive controller (d,e) and filter parameters (f).
The robustness of the controller is examined under varying reaction conditions, so $d_2(t)$ is selected as the time varying parameter. In simulations, it has been observed that the controller performance is adequate to successfully manage to control system under parametric uncertainty. If the control signals in Fig. 4(b) and Fig. 6(b) are compared, it is observed that the controller produces a control signal which varies to compensate the parametric uncertainty. It can also be deduced that the number of the support vectors increase in order to identify the uncertainty.

**V. CONCLUSION**

In this paper, a novel NARMA-L2 controller is proposed where online support vector regression is used to form submodels of NARMA-L2 controller. $\text{SVR}_{\text{NARMA-L2}}$ is employed to approximate the system model, then the parameters of the $\text{SVR}_{\text{NARMA-L2}}$ model and $\text{SVR}_{\text{NARMA-L2}}$ controller are derived via $\text{SVR}_{\text{NARX}}$ model of the system. The main contribution of the paper is that it justifies the use of an online $\text{SVR}_{\text{NARX}}$ model of the system directly to derive online $\text{SVR}_{\text{NARMA-L2}}$ controller as opposed to existing works in technical literature where $\text{SVR}_{\text{NARX}}$ models are generally utilized for adjusting the parameters of the traditional controllers by approximating system Jacobians. The performance of the controller is examined on CSTR system. The robustness of the controller against system parameter uncertainty and measurement noise have been examined. The results indicate that the proposed controller is quite successful in attaining low tracking error, suppressing measurement noise and parametric uncertainties. In future works, it is planned to extend the derivation of $\text{SVR}_{\text{NARMA-L2}}$ model via $\text{SVR}_{\text{NARX}}$ to develop new SVR type adaptive controller design methods.


REFERENCES


DEFINING THE PLANTATION ROLE TO MITIGATE THE URBAN HEAT ISLAND EFFECTS ON GLOBAL WARMING USING THERMAL SATELLITE SENSOR

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Abstract— Urban heat island (UHI) is one of the major effects on climate change based on human activities. Each land use/land cover (LULC) has an own temperature on the ground according to the structural characteristics (built up material), areal diversity (cover degree) and land physical dynamics (topography). Nowadays, many optical satellite sensors can record the thermal wavelength that is coming from the land surface and land surface temperature (LST) may be defined as degree using some allocation equations. Purpose of this research is to detect the plantation effects to mitigate UHI effect. In this extent, Landsat, thermal satellite sensor used to obtain planted and non-planted area thermal characteristics in same physical conditions. Plant effects were evaluated considering plant species on mitigation of global warming. Adana city that is located in Southern Turkey was used to be sample plot because of high potential on plant species and hot and dry climatic characteristics. As a result of the study, particularly, deciduous trees were reduced UHI effect more than conifers and Citrus sp, and Eucalyptus sp mitigation effects were found as 6.4 °C and 6.6 °C respectively. On the other hand, conifers were less effective than deciduous trees and Pinus brutia mitigation effect was calculated to be 5.6 °C. Additionally, irrigated grasslands were mitigated the UHI worse than other plant covers and temperature difference between bare ground and grasslands were 4.3 °C. In this frame, true plantation strategies were suggested to mitigate UHI effects.

Keywords— Urban heat island effect, Land use/cover, Climate regulation, Plantation, Landscape design

I. INTRODUCTION

Green vegetation cover has an important role in urban areas. Some of the many benefits of urban green spaces are: air and water purification, mitigation of the impact of environmental pollution, carbon sequestration, regulation of microclimate, habitat for urban wildlife, recreational, spiritual and therapeutic value as well as social integration [1-2-3].

Urban heat island is one of the most known issue on anthropogenic effect of global warming. Urban areas have an artificial characteristics because of built up materials such as concrete, asphalt and metallic structures [4]. Built up material can be warm more than water and vegetative surfaces. In addition to this, high “C” and CH₄ based gases keep warm air around the city atmosphere. So air temperature and LST of built up areas are generally more than around.

LULC types of the surface is of significant effect on UHI and lots of the study investigated that plant cover reduced UHI effects according to the cover degree and types [5-6]. Satellite remote sensing plays a vital role about defining land use/cover and monitoring dynamics between nature and human. Additionally, remote sensing provides time, energy and cost saving [7]. Thermal remote sensing is used widely to derive daytime and night time LST in many purposes. However, UHI detection is always one of the top issues in remote sensing studies. Particularly, ASTER, Landsat and TERRA-MODIS sensors were the most popular thermal sensors in the literature on UHI detection [8-9].

The purpose of this study is to obtain the plantation effects on UHI in plant type scale. Plant types were detected using high resolution aerial photos (HRAP) (0.45m), and UHI mitigation effect of the plants were compared each other at the same physical conditions (topography, air temperature and close location).

II. STUDY AREA AND DATA

A. Study Area

Adana city that is located in Southern Turkey was selected to be study area because of high temperature (53 °C max. and -6 °C min.) and population (1.71 million in the city) [10-11]. Adana is the 6th populous city of Turkey and region has a very good soil and climate characteristic for the sub-tropic plants and agriculture and there are almost 25m² total green areas (private and open) per person [12] (Fig. 1).
B. Dataset

Two main dataset were used to be Landsat Thematic Mapper (TM) thermal data and high resolution aerial photos (HRAP) of the study area. Landsat TM satellite has 30m spatial, 8 bit radiometric and almost 16 days temporal resolution. Landsat TM thermal sensor has 120m spatial resolution. However, it combined with other wavebands in false 30m spatial resolution [13]. August 2010 thermal TM data was used to obtain LST of each LULC

HRAP data was recorded in August 2009 by the Turkish Air Force Mapping Unit. One photo from the Adana City Centre was used in 45cm spatial resolution in visible range to define LULC and plant species. Red pine (Pinus brutia), Sour orange (Citrus sp.), Eucalyptus (Eucalyptus camaldulensis), and irrigated grasslands were studied to see the mitigation effect on UHI (Fig. 2).

III. METHODOLOGY

Method is contained three main stages; A) thermal image processing to obtain LST from Landsat TM data, B) digitalize the various land use and covers from HRAP, C) compering the mitigation effect of green and non-green cover areas.

A. Thermal Image Processing

Landsat TM thermal waveband shows LST in 8 bit data format as digital number (DN) value. Thermal DN values must be converted to blackbody temperature. The conversion process used is based on a look-up table published in Bartoliucci and Chang, (1988) [14]. Blackbody temperature is not a real LST, so it should be multiplied by emissivity constant of the surface material. According to Lillesand and Keifer, (1994) [15], vegetative surfaces and concrete and asphalt surfaces constants were between 0.9 and 0.96 respectively. However, this value is variable based on tree types and cover types, so application of the emissivity constant to blackbody temperature can be increase the error of the study. Therefore, blackbody temperatures were used alone to define the plantation effect to UHI.

B. Manuel Digitalize the LULCs

Four main plantation areas (red pine, eucalyptus, sour orange and grassland) and bareground (bare soil), asphalt, old built up and new built up areas were defined in geographical information system (GIS) environment from HRAP. Location of the each LULC was visited to find the pure areas.

Red pine is a typical Mediterranean forest tree and it has been used as afforestation inside and around the city. Eucalyptus was used to dry swamp areas, but today there is no flood risk anymore, and these areas has a shadow effect, particularly around recreational areas. It is not a very good tree for landscape design because of limitation on week body structure, and woods may fall in a windy weather easily. Sour orange tree is a landmark of the Adana city, and this region is provided 10% of the citrus production of Turkey. Additionally, sour orange trees are used in plant design frequently, especially near by the pavement roads. Grasslands are mostly irrigated human made areas in recreational places and house gardens. Baregrounds are open spaces or empty agricultural areas in the city. Asphalt refers roads and some big open land like school gardens or bazaar areas. Built up areas classified two part to be old and new. Old built up areas constructed in 1950s and 1960s. These lands haven’t too much space and streets are too narrow. New built up areas built in 2000s and there are big spaces between apartments.

C. Defining the Mitigation Effect

Mitigation effect of the plants were defined compering difference between bare grounds, urban built up and planted areas in plant type scale. So that not only plantation effect was detected, but also other LULC LST values were defined in same conditions such as asphalt, old and new urban built up and bare ground.
IV. RESULTS

Results were introduced in three part for better understanding the UHI mitigation effect of plantation; A) hard surfaces thermal characteristics, B) Thermal characteristics of planted areas and C) UHI mitigation analyses of the plantation.

A. Hard Surface Thermal Characteristics

Asphalt, baregrounds, old and new urban built up areas were defined as hard surfaces. These lands are typical urban areas, and one of the major reason of UHI effect is hard surfaces in the city. To detect the mitigation effect of plantation, we have to know thermal characteristics of the hard surfaces primarily.

Four sample plot has been selected to perform hard surfaces temperatures. Asphalt area was selected from a school garden because of enough bigness to match with TM thermal sensor. Bareground is an empty agricultural area just inside the city. Old and new built up areas located in old city and new city centres. Selected plot thermal values and descriptive statistics were shown in Fig. 3 and Table 1. The highest LST was observed in bareground as 40.8 °C mean value and the lowest LST was 37.2 °C in new urban built up areas. Standard deviation of the old built up areas around 1.04 °C and it was mean that variability of the old city areas were higher than other hard surfaces because of irregular urbanization.

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<tbody>
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<td>37.3</td>
<td>37.1</td>
<td>37.2</td>
<td>0.12</td>
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B. Thermal Characteristics of Planted Areas

A Red pine woodland, an eucalyptus woodland, sour orange garden and grassland area in the central park location were selected as sample plots. Descriptive statistics the thermal characteristics of these lands and LST values were presented in Fig. 4 and Table 2. The lowest LST value was observed in eucalyptus woodland to be 34.2 °C and the highest value was 36.6 °C in grassland areas. Standard deviation of the eucalyptus woodlands were higher than other plantation areas. Because, eucalyptus trees are located in riverside and some pixels were effected from cooling effect of the river due to mixed pixel effect. Some of the eucalyptus pixels were ignored in difference analyse and pure pixels were used.

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<tbody>
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<td>36.5</td>
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</tbody>
</table>
C. UHI Mitigation Analyses of the Plantation

Mean LST values of the each LULC was defined and mitigation effects on UHI were obtained. The mitigation effects of the plants were defined for eucalyptus (Eucalyptus camaldulensis), sour orange (Citrus sp.), red pine (Pinus brutia) and grassland area to be 6.6 °C, 6.4 °C, 5.6 °C and 4.3 °C respectively. Eucalyptus woodlands were the best to mitigate the UHI effect in Adana City, and sour orange also has a significant effects on UHI mitigation. Both trees are deciduous evergreen trees and effects of them are higher than other because of leaf areas and leaf water and chlorophyll a content. On the other hand, red pine is a conifer tree and leaf cover, water and chlorophyll content are less than deciduous trees. Irrigated grasslands are located in the recreational areas such as urban parks and roadsides and private house gardens generally. However, mitigation UHI mitigation effect was not as significant as trees (Table 3).

<table>
<thead>
<tr>
<th>Plantation</th>
<th>Mitigation Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bareground vs.</td>
</tr>
<tr>
<td>Sour orange</td>
<td>6.4</td>
</tr>
<tr>
<td>Eucalyptus</td>
<td>6.6</td>
</tr>
<tr>
<td>Red pine</td>
<td>5.6</td>
</tr>
<tr>
<td>Grassland</td>
<td>4.3</td>
</tr>
</tbody>
</table>

V. CONCLUSIONS

This paper focussed on the plantation effect to mitigate the UHI using remote sensing and GIS technologies. There were several research on UHI and surface material thermal characteristics using remote sensing or meteorological measurements in the literature [16-17-4]. This research is outshined from others in plant type scale. In this extent, site specific thermal data from planted areas were evaluated about UHI mitigation. Eucalyptus, red pine, sour orange and grassland areas were selected sample plots and compared with hard surfaces based on thermal characteristics.

In conclusion, evergreen deciduous trees (eucalyptus and sour orange) were found the best plants to mitigate UHI effect. Sour orange is a symbol plant of the Adana City and it may be used around the main roads frequently to reduce UHI effect. Eucalyptus is not a popular tree for the urban landscape because of weak body structure and it may be broken easily in windy weather. However, it used in plantation to dry swamp areas in the past, and now these trees are a part of the urban landscape. Red pine is a typical natural plant of the Mediterranean zone of Turkey also it is called as Turkish pine too. This tree can be used as afforestation tree in huge open areas to establish big recreational places near the city. Irrigated grasslands shouldn’t be preferred too much in urban landscape to provide cooling effect. Additionally, it needs water regularly in hot summer times and this is not good for water economy. Some alternative plant materials can be preferred instead of grasslands like perennial shrubs or little trees to cover the surface efficiently against UHI.

REFERENCES

An Integrated Approach for Sustainable Supplier Selection in Fuzzy Environment

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Abstract—The term sustainability, which means maintaining a balance or acting responsibly for the future, has come into prominence in many fields. One of the most crucial practices is cooperating with convenient collaborators and composing effective supply chains in terms of social, economic and environmental considerations. Therefore, sustainable supplier selection is getting more and more important to compete in rapidly changing environment. To deal with sustainable supplier selection problem, this study aims to determine the selection of appropriate suppliers and allocation of orders to them. The proposed approach operates in three stages. In the first stage, Fuzzy Decision Making Trial and Evaluation Laboratory is used to obtain the weights of the criteria considering sustainability perspective. In the second stage, by using Fuzzy Grey Relational Analysis, a set of suppliers are ranked and their suitability scores are calculated. In the last stage, optimal order quantities to be provided by the suppliers are obtained via fuzzy linear programming including imprecise data of demand, error rate and capacity.

Keywords—Sustainable supplier selection, fuzzy logic, DEMATEL, grey relational analysis, fuzzy linear programming

I. INTRODUCTION

Nowadays, it has been obligatory to analyze customers' requirements precisely and meet the demand in short time. While meeting the demand, the production technology should also be considered and improved to gain flexibility in production process. Moreover, the limited resources of the world should be utilized effectively considering the future. Companies should make the decisions taking into account economic dimension of sustainability as well as social and environmental dimensions. Sustainable supplier selection problem, the main topic of our study, means to select the suppliers in an effective way to provide sustainability with all dimensions.

This study which proposes an integrated approach for sustainable supplier selection is organized as follows. In section two, a literature review on the relevant subject is presented. In section three, the problem and the proposed approach are explained. The implementation of the proposed methodology is illustrated in section four. In the last section, the paper is concluded with some future research directions.

II. LITERATURE REVIEW

In today’s highly competitive business life, profitability of the company has direct relation with its own source consumption and internal productivity, as well as the effectivity of the overall supply chain. Therefore, supplier selection and supplier performance evaluation are the key elements for composing effective supply chains. In the literature, numerous studies exist on supplier selection problem. The problem includes more than one criterion and with this aspect it is an example of multi criteria decision making (MCDM) problems. For addressing the solution of the problem, different MCDM methods have been applied.

Sustainable supplier selection has been a prominent topic since the middle of 1990s. Brandenburg et al. [1] and Zimmer et al. [2] reviewed the literature of the mathematical models for sustainable supplier management in detail. They also summarized the sustainable supplier management approaches into two groups such as integrated models and single models which consist of qualitative, mathematical programming, mathematical analytical, artificial intelligence [2]. Azadi et al. [3] and Yousefi et al.[4] applied robust dynamic and fuzzy data envelopment analysis method for sustainable supplier selection problem. Trapp and Sarkis [5] proposed an optimization model using binary integer programming for simultaneous supplier selection and development. Orji and Wei [6] added the time dimension to decision making process and suggested a dynamic framework consisting of system dynamics and simulation for selecting appropriate suppliers considering sustainability factors. The results of the proposed approach were compared to the results derived from TOPSIS method. Su et al. [7] assumed that there can be incomplete information throughout the decision making process and proposed an approach to compensate incomplete information using grey theory and applied DEMATEL. Amindoust et al. [8] and Ghadimi and Heavey [9] implemented fuzzy inference system to determine the suitable suppliers. Azadnia et al. [10] proposed an integrated approach based on fuzzy AHP, neural networks, clustering and TOPSIS. Shaw et al. [11] proposed an integrated approach using fuzzy AHP to calculate the weights of the criteria and fuzzy multi-objective linear programming model to allocate the orders. Büyükozkkan and Çifçi [12] developed an integrated methodology using fuzzy ANP, DEMATEL and TOPSIS for sustainable supplier evaluation and selection. Bai and Sarkis [13] suggested a supplier evaluation model based on rough set theory and grey system theory to deal with the information vagueness.

The literature review has stated that the importance of sustainable supplier selection problem has increased recently. To find a solution to this problem, most studies have focused on integrated approaches instead of single models. Another assessment from the review is that fuzziness and vagueness in decision making process is substantially taken into consideration. Motivated from these inferences, we propose an
integrated fuzzy approach for this problem. The proposed approach first determines the appropriate sustainable suppliers and then allocates the orders to these suppliers. The details are given in the following section.

III. THE PROPOSED INTEGRATED METHODOLOGY

This study integrates fuzzy DEMATEL, fuzzy grey relational analysis and fuzzy linear programming to solve sustainable supplier selection problem and operates in three stages. In the first stage, we used fuzzy DEMATEL to calculate the weights of the criteria. In the second stage, fuzzy grey relational analysis was used to rank suppliers according to sustainability dimensions. In the third stage, the weights of the suppliers which were calculated in the previous stages, were incorporated into the fuzzy linear programming model to obtain the optimum order sizes of the appropriate suppliers. The main steps of the proposed integrated approach are shown in Fig.1.

IV. A CASE STUDY

In this section, the illustration of the proposed model is shown. This study particularly focuses on the sustainable supplier selection problem of an online retailer store located in Canada that works with different travertine-marble suppliers located in Turkey. Recently, it needs to search for sustainable, reliable and constant suppliers due to the problems about orders faced with the previous suppliers. Within this scope, three most demanded products and four possible suppliers are determined. Before the application of the proposed approach, the criteria which are used for supplier selection considering sustainability factors are determined. Therefore, the criteria are determined based on triple bottom line [14] and explained in Table 1.

---

![Diagram of the proposed methodology](image)

**TABLE I**

<table>
<thead>
<tr>
<th>Criteria used in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic criteria [15]</strong></td>
</tr>
<tr>
<td>$C_7$ - Cost</td>
</tr>
<tr>
<td>$C_2$ - Productivity</td>
</tr>
<tr>
<td>$C_3$ - Capacity</td>
</tr>
<tr>
<td>$C_4$ - Continuity</td>
</tr>
<tr>
<td>$C_5$ - Lead time</td>
</tr>
<tr>
<td>$C_6$ - Quality</td>
</tr>
<tr>
<td>$C_7$ - Production technology</td>
</tr>
<tr>
<td>$C_8$ - Responsiveness</td>
</tr>
</tbody>
</table>
A. Fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) Implementation

DEMATEL method is mainly based on graph theory and was conducted by Geneva Research Centre of the Battelle Memorial Institute [17]. DEMATEL is a comprehensive method for building and analysing a structural model involving causal relationships between complex factors [7]. This aspect helps the decision maker to reveal and visualize the interdependence relationships between criteria and sub-criteria. Furthermore, it lets the decision process come to a conclusion relatively easily and reliably. The basic steps and application of fuzzy DEMATEL method is described as follows.

Each criterion which is determined based on sustainability dimensions is written throughout columns and rows. Elements of the matrix show the pairwise comparison values of the criteria and are determined by means of linguistic variables. In this part we used the linguistic scale shown in Table 2.

The direct relation matrix (A) is established according to the expert’s remarks and shown as follows.

The normalized direct relations matrix is obtained [19] and shown partly in Eq. (2).

Once the normalized direct relation matrix is obtained, the total relation matrix is established [19]. Total relation matrix can be separated into separate sub matrices i.e., $X_l$, $X_m$, $X_s$ to overcome the following defuzzification process easily. To illustrate this step, Eq. (3) is given which includes $X_l$ and $T_l$ matrices.

Several methods can be used for defuzzification process but we adopted an extensive defuzzification method of converting fuzzy data into crisp scores (CFCS) which was introduced by Opricovic and Tzeng [20]. The steps of defuzzification process consist of normalization, right and left hand side normalized values, total normalized value and crisp values. The application of defuzzification illustrated partly in Table 3.

The next step includes calculating the sum of rows and the sum of columns separately denotes as vectors D and R within the total relation matrix. The weights of the criteria are obtained via D and R values [19] and shown in Table 4.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>LINGUISTIC SCALE [18]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linguistic variable (effect)</td>
<td>Value</td>
</tr>
<tr>
<td>No - N</td>
<td>0</td>
</tr>
<tr>
<td>Very low - VL</td>
<td>1</td>
</tr>
<tr>
<td>Low - L</td>
<td>2</td>
</tr>
<tr>
<td>High - H</td>
<td>3</td>
</tr>
<tr>
<td>Very high - VH</td>
<td>4</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Table 3</th>
<th>DEFFUZZIFICATION TABLE VIA CFCS METHOD [20]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triangular fuzzy numbers</td>
<td>Normalization</td>
</tr>
<tr>
<td>$l$</td>
<td>$m$</td>
</tr>
<tr>
<td>$C_2$</td>
<td>1.024</td>
</tr>
<tr>
<td>$C_2$</td>
<td>0.146</td>
</tr>
<tr>
<td>$C_1$</td>
<td>0.024</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>$C_{11}$</td>
<td>1.042</td>
</tr>
</tbody>
</table>
B. Fuzzy Grey Relational Analysis (GRA) Implementation

Grey relational analysis method is mainly based on grey system theory which was introduced by Deng and used to show the correlations between the references and alternatives of a system [21]. The basic steps and application of fuzzy GRA method is described as follows.

The method starts with generating the decision matrix which shows the evaluation of the suppliers according to decision maker. The linguistic scale which is used in this part is shown in Table 5.

<table>
<thead>
<tr>
<th>Linguistic variable (alternative ratings)</th>
<th>Triangular fuzzy number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor - P</td>
<td>(0.0, 0.6)</td>
</tr>
<tr>
<td>Fair - F</td>
<td>(4.7, 10)</td>
</tr>
<tr>
<td>Good - G</td>
<td>(8.1, 14)</td>
</tr>
<tr>
<td>Very good - VG</td>
<td>(12, 15, 18)</td>
</tr>
<tr>
<td>Excellent - E</td>
<td>(16, 20, 20)</td>
</tr>
</tbody>
</table>

After selecting the scale, the decision matrix is established according to the expert’s remarks as shown in Table 6.

<table>
<thead>
<tr>
<th>Supplier</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>G</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C2</td>
<td>F</td>
<td>V</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C3</td>
<td>G</td>
<td>E</td>
<td>V</td>
<td>G</td>
</tr>
<tr>
<td>C4</td>
<td>E</td>
<td>V</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C5</td>
<td>F</td>
<td>V</td>
<td>G</td>
<td>V</td>
</tr>
<tr>
<td>C6</td>
<td>V</td>
<td>E</td>
<td>V</td>
<td>G</td>
</tr>
<tr>
<td>C7</td>
<td>G</td>
<td>V</td>
<td>V</td>
<td>G</td>
</tr>
<tr>
<td>C8</td>
<td>F</td>
<td>V</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>C9</td>
<td>F</td>
<td>G</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C10</td>
<td>P</td>
<td>V</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>C11</td>
<td>P</td>
<td>V</td>
<td>E</td>
<td>V</td>
</tr>
<tr>
<td>C12</td>
<td>F</td>
<td>V</td>
<td>V</td>
<td>G</td>
</tr>
</tbody>
</table>

The normalized decision matrix is obtained [22] and shown partly in Eq. (4).

\[
x = \begin{pmatrix}
(0.571429, 0.785714, 1) & (0.222222, 0.308889, 0.555556) & \cdots & (0.222222, 0.488889, 0.555556) \\
(0.571429, 0.785714, 1) & (0.488889, 0.555556, 1) & \cdots & (0.488889, 0.656565, 1) \\
(0.571429, 0.785714, 1) & (0.444444, 0.611111, 0.777778) & \cdots & (0.444444, 0.666667, 0.833333) \\
(0.571429, 0.785714, 1) & (0.444444, 0.666667, 0.833333, 1) & \cdots & (0.444444, 0.666667, 0.833333, 1)
\end{pmatrix}
\] (4)

The reference series are obtained [22] and shown partly in Eq. (5).

\[
\tilde{r} = \begin{pmatrix}
(0.571429, 0.785714, 1), (0.666667, 0.833333, 1), \cdots , (0.666667, 0.833333, 1)
\end{pmatrix}
\] (5)

The distance between the reference value and each comparison value is computed [22]. The grey relational coefficient is calculated [22] via the distance matrix and grey relational coefficient matrix shown partly in Eq. (6).

\[
\gamma = \begin{pmatrix}
1 & 0.466666 & 0.520038 & 1 & 0.486638 & \cdots & 0.486638 \\
1 & 1 & 1 & 0.685101 & 1 & \cdots & 1 \\
1 & 0.654602 & 0.685101 & 0.520038 & 0.654602 & \cdots & 0.654602 \\
1 & 0.654602 & 0.520038 & 0.520038 & 0.654602 & \cdots & 0.654602
\end{pmatrix}
\] (6)

In the last step of fuzzy GRA, the elements of grey relational coefficient matrix are multiplied by the weights of the criteria which was obtained from DEMATEL method. The grey relational grades which shows the importance values of the suppliers are shown in Table 7.

C. Fuzzy Linear Programming Implementation

Each element of classical linear mathematical models has certain values and these models consist of parameters, decision variables, objective function and constraints. Fuzzy linear programming mathematical models consist of the same components but they have fuzziness and vagueness in it. As a result of that, they have different ways to solve the models [23]. In our study, we have vagueness in capacities, error rates and demands which compose the right hand side values of constraints. Therefore, the most suitable fuzzy linear model for our problem is the approach which was introduced by Verdegay [24]. This method is a non-symmetric model and needs to conversion to parametric programming decision model [25].

1) Index:
- \( i \): Supplier
- \( j \): Product

2) Decision Variable:
- \( A_{ij} \): Amount of product \( j \) provided by supplier \( i \)

3) Parameters:
- \( N \): Number of suppliers \((N=4)\)
- \( M \): Number of products \((M=3)\)
- \( w_i \): The grey relational grade of supplier \( i \) \((w_1=0.190, w_2=0.307, w_3=0.268, w_4=0.235)\)
- \( D_j \): The demand of product \( j \) \((D_3=300, D_3=400, D_3=600)\)
\( C_i \): The capacity of supplier \( i \) for the company \( (C_1=400, C_2=500, C_3=200, C_4=450) \)

\( q_i \): The error rate of supplier \( i \) \( (q_1=0.12, q_2=0.06, q_3=0.08, q_4=0.09) \)

\( Q_j \): The desired error rate for product \( j \) \( (Q_1=0.10, Q_2=0.08, Q_3=0.09) \)

4) Objective Function:

The objective function of the model aims to maximize the value of purchasing (TVP) and shown by Eq. (7).

\[
\text{Max} Z = \sum_{i=1}^{N} \sum_{j=1}^{M} (A_j \times w_j)
\]

5) Constraints:

Eq. (8) illustrates the demand of each product is satisfied. Eq. (9) shows the equality of the sum of products provided by supplier and the capacity of related supplier. Eq. (10) guarantees to maintain supplier’s error rate below than desired error rate for the product. Eq. (11) shows that the decision variables are positive integers.

\[
\sum_{j=1}^{M} A_j \geq D_j \quad \forall j \in M
\]

\[
\sum_{j=1}^{M} A_j \leq C_i \quad \forall i \in N
\]

\[
\sum_{j=1}^{M} (q_j \times A_j) \leq (Q_j \times D_j) \quad \forall j \in M
\]

\[ A_j \geq 0 \]

After the construction of the model, tolerances for demand, capacity and error rate are determined via decision maker’s remarks. The tolerances are respectively 100 units, 100 units and 0.5. Ten membership functions for the right hand side values are obtained from the tolerances. The first membership function is shown in Eq. (12).

\[
\mu(z) = \begin{cases} 
1 & A_1 + A_2 + A_3 + A_4 < 300, \\
\frac{1 - (A_1 + A_2 + A_3 + A_4) - 300}{100} & 300 \leq A_1 + A_2 + A_3 + A_4 \leq 400, \\
0 & A_1 + A_2 + A_3 + A_4 > 400, 
\end{cases}
\]

\( \lambda \) cuts are determined for the right hand side values. Then mathematical model is converted to parametric linear model via \( \theta=(1-\lambda) \) transformation. The final mathematical model is shown in Eq. (13).

\[
Z = \sum_{i=1}^{N} \sum_{j=1}^{M} (A_j \times w_j) \rightarrow \text{Maximum}
\]

\[
\begin{align*}
A_1 + A_2 + A_3 + A_4 &= 300 + 100\theta \\
A_1 + A_2 + A_3 + A_4 &= 400 + 100\theta \\
A_1 + A_2 + A_3 + A_4 &= 500 + 100\theta \\
A_1 + A_2 + A_3 + A_4 &= 600 + 100\theta \\
A_1 + A_2 + A_3 + A_4 &\leq 30 + 300 \times 0.05\theta \\
A_1 + A_2 + A_3 + A_4 &\leq 32 + 400 \times 0.05\theta \\
A_1 + A_2 + A_3 + A_4 &\leq 54 + 600 \times 0.05\theta 
\end{align*}
\]

Parametric linear programming model was solved in LINDO 6.1 for different \( \theta \) values and the order quantities which are shown in Table 8 are obtained.

The decision maker has different alternatives for the selection of suppliers within tolerances. According to different levels of demand, capacity and error rate, the quantities of products to be provided by the suppliers can be determined from Table 8.

V. CONCLUSIONS

In this paper, an integrated approach is proposed for sustainable supplier selection problem using fuzzy DEMATEL, fuzzy GRA and fuzzy linear programming. The weights of the criteria based on sustainability dimensions are determined via DEMATEL. The importance values of suppliers are calculated using GRA. These outputs are used as inputs for fuzzy linear programming model and the quantities of products to be provided by the suppliers were obtained. For future research, a multi-objective mathematical model considering the minimization of total costs can be built to obtain a more realistic outcome. Another interesting research direction can be to add more realistic constrains such as carbon gas emissions into the models.

| \( A_{11} \) | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
| \( A_{12} \) | - | - | - | - | - | - | - | - |
| \( A_{13} \) | - | - | - | - | - | - | - | - |
| \( A_{21} \) | 450 | 450 | 450 | 420 | 200 | 300 | 290 | 350 |
| \( A_{22} \) | 150 | 150 | 150 | 150 | 350 | 150 | 220 | 150 |
| \( A_{23} \) | 250 | 240 | 220 | - | 180 | 90 | 150 | - |
| \( A_{24} \) | 50 | 50 | 50 | 50 | 250 | 50 | 120 | 50 |
| \( A_{31} \) | - | - | - | - | - | - | - | - |
| \( A_{32} \) | - | - | - | - | 200 | - | 70 | - |
| \( A_{33} \) | 550 | 540 | 520 | - | 480 | 390 | 450 | - |
| \( Z \) | 422.35 | 414.25 | 398.05 | 381.85 | 365.65 | 349.45 | 341.35 | - |
REFERENCES


The Minimization of Torque Ripples of Segmental Type Switched Reluctance Motor by Particle Swarm Optimization

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Abstract—In this study, we realized a controller design which can reduce torque ripple of 10/8 Switched Reluctance Motor (SRM). To perform the study, a Switched Reluctance Motor with 5 phase, U type segmental rotor was used. The control of the SRM was actualized by bipolar converter used H-bridge topology. The control signals of converter are obtained by control circuit designed by using dsPIC33E (PS12MU810). One of the reasons of the current ripples in the SRM is the ON-OFF times in a period of the control signals. When the ripples of the current reduced, the ripple of torque of the SRM also reduced. Therefore, in this study, the ON-OFF times in a period of phase control signals were determined by an algorithm used particle swarm optimization. When SRM was controlled by this algorithm developed, the decreasing of its torque ripples was determined.

Keywords—Segmental Type Switched Reluctance Motor, H-Bridge Converter, dsPIC33, Torque Ripple, PSO

I. INTRODUCTION

Switched Reluctance Motors (SRM) are the electrical machines which have been used widely in recent years. They have a simple and enduring structure, low-cost, low inertia, high speed, high efficiency and a high performance [1]. Whereas the place of the use of SRMs is increasing, their torque ripples and the acoustic noise are the most important disadvantages for them [2]. In most of the works performed so far, this problem has been tried to be solved through the physical structure of the motor, drive circuit or control circuit. In the works that were carried out, a new 5-phase and U shape SRM with a segmental rotor was designed and it was stated that this new designed SRM produced more torque than the classical SRM [3, 4].

Many studies have been performed to reduce the torque ripple that is the most important problem of SRMs. The ripples in the torque were minimized by using a method called Torque Sharing Function (TSF). In this method, the reference torque value was directly turned into reference analytical wave by analytical method. It is a study performed using this method and arranging triggering angles. Linear and sinusoidal TSF method was used and compared, and the torque ripples were minimized [5]. In the control of 8/6 SRM, the starting and ending angles of the triggering angles of power switches were determined and a new approach was brought [6]. For SRM a direct torque control was recommended with Lyapunov function stability based. The magnetic properties of SRM have an indirect structure (because torque, phase current and rotor positions have complicated positions). Torque ripples were minimized through the method recommended in this study [7]. The effects of the stator pole shape over moment ripples were searched in SRMs. As a result of the studies, a motor design with a high average moment production and with low moment ripples was fulfilled [8]. It is stated that the converter structure that is used in the control of SRM affects the overall performance of the system and the loss of the motor and torque ripples are the factors to be taken into account while evaluating the motor [9]. Besides, another study was also carried out to determine proportion between rotor and stator thread width inside SRM for a high torque and proper output power [10]. By using B-spline neural network (BSNN), torque ripples of the SRM were reduced. Closed loop torque control was performed using an online torque estimator. Because of local weight updating algorithm used for BSNN, a proper phase current profile was obtained as real-time so as to reduce torque ripples and it was expressed that it had a good dynamic performance according to the changes in the desired torque. It was explained that the suggested schema did not require a current controller with high bandwidth and the validity of the schema was shown by simulations and experimental results [11]. Speed regulation was carried out by using Adjustable Fuzzy Cerebellar Model Articulation Controller [12]. ANN model was used to determine the rotor position of SRM. Three methods were compared to each other: Traditional ANN, Developed ANN and the method where developed ANN and curve fitting were used together [13]. Sudden torque control was performed by using linear magnetic model. Torque control was performed by determining commutation angle. It was seen in the results of the simulation and experiment that torque ripple decreased [14]. The speed of SRM was checked by using the method of Takagi-Sugeno-Kang (TSK) Fuzzy Controller [15]. A new stable technique was developed for the speed control applications of Switched Reluctance Motor and the mathematical model of SRM was used in this technique. In this study, Second Order Sliding Mode Control (SOSMC) and a super twisting algorithm schema were used [16]. The speed control of on grid Switched Reluctance Generator that was...
driven by wind turbine was checked by using Adaptive ANN controller [17]. A 5-phase segmental type SRM was designed to increase the torque in SRMs. Also, a bipolar driving strategy was used to increase the torque even more. A traditional full bridge converter was used. A higher torque output was obtained as a result of bipolar driving method [18].

A new SRM was designed by placing auxiliary winding and permanent magnet in the stator yoke of Switched Reluctance Motor. The traditional SRM and newly designed SRM were tested by asymmetrical half-bridge [19]. 50 kW- SRM was designed for hybrid electrical vehicles (Toyota Prius 2003). Designed SRM and stable magnetic synchronous motor were compared. It was seen that the performance of the newly designed SRM was 95% and it reached the targeted torque at the rate of 85% [20]. The vibration and the noise of the motor could be reduced by the changes in the design and control system of the motor and it was also stated that triggering angles affected the torque ripple of the motor [21].

In this study, optimum triggering angle values were determined so as to reduce the torque ripples of the 5-phase 10/8 segmental type SRM (ST-SRM). Particle Swarm Optimization (PSO) was used to determine optimum triggering angles. Triggering angle values which were determined by PSO were applied to H-bridge driving circuit by SnadPIC PIC Microchip Development Board with dsPIC33EP512MU810 on it and ST-SRM was checked as a bipolar. As a result of the experimental study, the effects of triggering style of SRM motor on motor torque was also determined.

II. SEGMENTAL TYPE SWITCHED RELUCTANCE MOTOR

In this study, 10/8 segmental type SRM (ST-SRM) that has a different rotor type from a classical SRM was used. The rotor of the ST-SRM motor consists of both the parcels formed by laminated silicon steel and an aluminium block in which these parcels are placed. The aluminium block that is used in rotor structure functions as a flux barrier and this speciality isolates the motor from classical SRMs. It can be called as U shape segmental type motor because the rotor type of segmental type SRM is U shape. The sectional view of Segmental Type Switched Reluctance Motor is seen in Figure 1 [22].

The features of Segmental Type Switched Reluctance Motor are given at Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Features</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Maximum moment at 5 A</td>
<td>2.34 Nm</td>
</tr>
<tr>
<td>2</td>
<td>Maximum inductance</td>
<td>13 mH</td>
</tr>
<tr>
<td>3</td>
<td>Stator phase resistance</td>
<td>0.86 Ω</td>
</tr>
<tr>
<td>6</td>
<td>Magnetic field energy at 5 A</td>
<td>0.848 Joule</td>
</tr>
<tr>
<td>7</td>
<td>Moment/weight ratio</td>
<td>0.22 Nm/kg</td>
</tr>
<tr>
<td>8</td>
<td>Phase number</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Stator/Rotor Configuration</td>
<td>10/8</td>
</tr>
<tr>
<td>14</td>
<td>Stator phase angle</td>
<td>0.314 rad</td>
</tr>
<tr>
<td>15</td>
<td>Rotor phase angle</td>
<td>0.331 rad</td>
</tr>
</tbody>
</table>

III. INDIRECT MATHEMATICAL MODEL OF SEGMENTAL TYPE SWITCHED RELUCTANCE MOTOR

When magnetic hysteresis loss, Eddy current loss and phase winding are omitted, the mathematical expressions of SRM are given in Equation (1) [23].

\[ V_i = R_k j_k + \left( L_k + j_k \frac{\partial L_k}{\partial \theta} \right) \frac{dj_k}{dt} + j_k \frac{\partial L_k}{\partial \theta} \frac{d\theta}{dt} \] (1)

When phase winding mutual inductance is omitted in Equation (1), \( \theta \) refers to rotor position, \( j_k \) refers to current, \( L_k \) refers to winding inductance for each phase, \( R_k \) refers to phase winding resistance.

The rotor position of the motor can be converted to angular speed as in Equation (2).

\[ \omega = \frac{d\theta}{dt} \] (2)

In this case, when the expression in Equation (1) is written in its place in Equation (2), it is also described as in Equation (3) that is mathematical model of equivalent circuit of SRM.

\[ V_i = R_k j_k + \left( L_k + j_k \frac{\partial L_k}{\partial \theta} \right) \frac{dj_k}{dt} + \omega j_k \frac{\partial L_k}{\partial \theta} \] (3)

In Equation (3), it is seen that the source voltage equals the total of 3 voltages. To show k phase circuit, the first voltage is the voltage drop in the resistance; the second voltage is the transformer electromotive force caused by the changed flux because the current was charged; the third one is about electromechanical energy of SRM caused by the changed flux because the position of the rotor was changed [24].

Torque statement of one phase of SRM is given in Equation (4).

\[ T_e = \frac{1}{2} j_k \frac{dL_k}{d\theta} \frac{d\theta}{dt} \] (4)

In SRMs, m is the phase number and total electrical torque produced in the motor can be calculated as in Equation (5).

\[ T_e = \sum_{k=1}^{m} T_e \] (5)
Mechanical modelling of SRM can be calculated as in Equation (6).

$$T = T_r - T_L = J \frac{d\omega}{dt} + B\omega$$  \hspace{1cm} (6)

In Equation (6), $\omega$ is angular speed, $T_L$ is load torque, $B$ is friction coefficient and $J$ is inertia.

Torque ripple of SRM is calculated as in Equation (7).

$$\%T_{\text{ripple}} = \frac{T_{\text{max}} - T_{\text{min}}}{T_{\text{avg}}} \times 100$$  \hspace{1cm} (7)

IV. ACCURACY OF THE MODELLING

Accuracy is a value that shows how close the calculated value is the measured value. Equation (8) is used for every data value to determine the error value between the value measured and the value that is calculated or estimated.

$$\delta_i = \frac{|R_i - R_{i0}|}{R_i} \times 100$$  \hspace{1cm} (8)

Here $\delta_i$ is the error of each data, $R_i$ is estimated results, $R_{i0}$ is experimental results and $i$ is data index.

Equation (9) is used to determine total errors of whole model.

$$\Delta = \frac{1}{n} \sum\delta_i$$  \hspace{1cm} (9)

Here $\Delta$ is the estimated accuracy of the model, $n$ is number of data.

Error ratio of the torque ripple was determined by using Equation (8) and (9).

V. PARTICLE SWARM OPTIMIZATION

PSO is a heuristic algorithm that was developed by James Kennedy and Russell Eberhart in 1995 [25]. This is a heuristic algorithm that exists in all living creatures in the nature and based on social intelligence. Human beings share the knowledge by talking, the birds make use of each other to find their directions and a school of fish decides their behavior through a mutual decision and all these attitudes are the evidence of a social being. PSO was developed being inspired of the birds’ making use of each other for directions and the mutual behaviors of the fish [26]. PSO shows similarities with evolutionary optimization techniques like GA but it does not have evolutionary operators (crossbreeding and mutation). The solutions called as particles in PSO travel in the problem space by following the best results within the solutions.

PSOs are easier to carry out when compared to GA and the number of the parameters to be arranged is lower. For this reason, PSOs are used in many fields today as an application. [26]. Flow chart of PSO is seen in Figure 2.

Figure 2. PSO flow chart

General steps of PSO algorithm can be listed as follows [27]:

1. Population is created. Initial value and the speed of each particle are casually assigned.
2. Suitability value of each particle is calculated according to the objective function.
3. The best value of the particle is found. The suitability value found out in the previous step is compared to the best personal value (pbest) that is in the memory of the particle. If the result found out in the previous step is better than the current “pbest” value, the new value is changed as “pbest.”
4. The best global particle is found. The suitability value that is calculated for each particle in the second step is compared to the best global value “gbest” that is kept in the memory of the program. If there is a better result, this result is changed with “gbest.”
5. The speed and speed factor of the particle are arranged according to Equation (10) and the position of the particle is arranged according to Equation (11). $r_1$ ve $r_2$ are the numbers produced between [0,1].

$$v_{i+1} = w \cdot v_i + c_1(p_{\text{best}i} - x_i) + c_2(p_{\text{gbest}i} - x_i)$$  \hspace{1cm} (10)

$$x_{i+1} = x_i + v_{i+1}$$  \hspace{1cm} (11)

6. The processes between the steps of 2-5 are repeated until the ending condition or conditions are fulfilled.

VI. TEST FUNCTIONS

To determine the accuracy of the PSO algorithm software, algorithm was worked on the functions that were known before and their performances were evaluated. For this reason, PSO algorithm was tried by using some functions that were known in the literature and the accuracy of the unit software was determined. A test function group that consists of the Benchmark functions seen in the Table 2 was created so as to inspect the accuracy of the unit software prepared in MATLAB. The mathematical expressions in the test functions at Table 2 were tried in PSO [28-30]. The particle number in PSO whose unit software was performed was approached as 100 and learning coefficient was approached as 2. Ending criteria was accepted as 1000 for iteration number or 0 for error value.
### Table 2. Test Functions

<table>
<thead>
<tr>
<th>Function name</th>
<th>Function</th>
<th>Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Sphere</td>
<td>$F_1 = \sum_{i=1}^{4} (x_i - x_i^*)^2$</td>
<td>$[-150.75]$</td>
</tr>
<tr>
<td>F2 Rosenbrock</td>
<td>$F_2 = \sum_{i=1}^{2} 100 (x_i - x_i^*)^2 + (x_i - 1)^2$</td>
<td>$[-50, 25]$</td>
</tr>
<tr>
<td>F3 Rastrigin</td>
<td>$F_3 = \sum_{i=1}^{2} [10 + (x_i - 10 \cos(2\pi x_i))^2]$</td>
<td>$[-50, 25]$</td>
</tr>
</tbody>
</table>

Instead of working PSO algorithm once and getting a result from it, the average of the results that are received after working it many times are accepted. For this reason, PSO algorithm was worked 20 times and the averages were accepted as results, then they were given in Table 3.

For the test functions, global minimum solutions that were carried out in the previous studies were given in Table 4.

### Table 3. Solutions of the Test Functions

<table>
<thead>
<tr>
<th>Algorithm Functions</th>
<th>Global Minimum VALUES</th>
<th>PSO Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>0</td>
<td>2.65E-8</td>
</tr>
<tr>
<td>F2</td>
<td>0</td>
<td>6E-4</td>
</tr>
<tr>
<td>F3</td>
<td>0</td>
<td>14.8E-2</td>
</tr>
</tbody>
</table>

### VII. MATERIAL AND METHOD

In this study, the reduction of the ripple values in the torque was aimed to reduce by arranging the ON and OFF time of the signal when the phase windings are energized. Here, the PSO algorithm determines signals to be used angularly. As seen in Figure 3, it was thought that one triggering signal was applied to one phase. 3 different position values seen in the figure were optimized. This means that the number of the factors in the algorithm is 3. The number of the factors was determined as 3 because increasing this number would make it difficult for the current to reach the desired value. Phase limit in the Figure 3 was determined as the ending position of the each phase. The limits of the factors in the PSO algorithm were determined as $4 \leq \theta_1 \leq 8$, $8 \leq \theta_2 \leq 13$, $13 \leq \theta_3 \leq 17$ by taking into account the increasing and decreasing times of the current.

### Table 4. PSO algorithm result and torque ripple

<table>
<thead>
<tr>
<th>PSO</th>
<th>$\theta_1$</th>
<th>$\theta_2$</th>
<th>$\theta_3$</th>
<th>$T_{\text{ripple}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$7.2^0$</td>
<td>$11^0$</td>
<td>$16.4^0$</td>
<td>$%33.4$</td>
</tr>
</tbody>
</table>

### VIII. EXPERIMENT SETUP AND THE RESULTS

In this study, H-Bridge converter structure, with the control of dsPIC33EP512MU810, was used for the segmental type SRM.

A phase circuit of the H-Bridge that was designed in Proteus program is given in Fig. 4.

![Fig. 4. A driving circuit and H-Bridge of a phase](image)

In this study, the motor was run as bipolar. The sequence of trigger signals of 5 phase segmental type SRM is given in Table 5 [3]. In the performed studies, the sequence of the triggering was performed as in Table 5.

### Table 5. Triggering Sequence of the Phases

<table>
<thead>
<tr>
<th>0-18</th>
<th>18-36</th>
<th>36-54</th>
<th>54-72</th>
<th>72-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Phase</td>
<td>0</td>
<td>+</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>B Phase</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>C Phase</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>D Phase</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>E Phase</td>
<td>0</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The experiments were performed using the testing apparatus set up in Fig 5.

![Fig. 5. The picture of the testing apparatus](image)
In this study RD300 model of FUTTEK brand, with 0-10 Nm measuring range, was used to measure motor torque. The signal received from the torque sensor was increased to 0-5 V voltage level using FUTTEK brand CSG110 amplifier. The motor speed was measured by 3600 pulse Autonics brand encoder. Motor current was measured using ACS712 current sensor. The signals received from current and torque sensors and the encoder were transferred to the computer, to the interface designed at Visual C# by SnadPIC PIC Microchip Development Board. In the designed interface, torque and current interface were both displayed in the screen and saved in the data base.

7.2°, 11°, 16.4° triggering angles that were determined by PSO algorithm and the torque ripple of the ST-SRM that was controlled as bipolar were calculated as 31.9 % as seen in the interface screen in Figure 6.

Torque ripple values of PSO obtained as a result of the algorithm and the torque ripple values obtained experimentally are seen at Table 6.

Table 6. PSO algorithm and experimental results

<table>
<thead>
<tr>
<th>Torque Ripple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque Ripple (PSO)</td>
</tr>
<tr>
<td>Torque Ripple (Experimental)</td>
</tr>
<tr>
<td>Error Value (%)</td>
</tr>
</tbody>
</table>

As seen at Table 6, there is a 5.83% error value between the torque ripple values obtained by PSO algorithm and obtained experimentally. This value shows that PSO gave a successful performance for a system with a quite difficult modeling. Besides, in the previous studies performed on ST-SRM which was used in this study, the motor had a 56% torque ripple [3, 4]. For this reason, the control signal of the motor was changed in this study and a 40.35% reduction was obtained in the torque ripple.

IX. CONCLUSIONS

In this study, the controlling of the 5-phase 10/8 Segmental Type SRM was carried out by H-bridge converter topology that was controlled by dsPIC33EP512MU810. The angle values of the triggering signal recommended for the control of ST-SRM were determined by means of PSO algorithm. When compared to the previous studies, there was a 40.35% reduction in the torque ripple of the ST-SRM that worked with the values obtained from PSO algorithm. This shows that heuristic algorithm could produce a successful result about torque ripple that is the most important disadvantage of the SRMs. In the next studies, by using different heuristic algorithm or changing the parameter values of the PSO, their effects on the torque ripple of the motor can be searched.

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REFERENCES


A new subspace based solution to background modelling and change detection

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Abstract— For surveillance system, the background subtraction plays an important role for moving object detection with an algorithm embedded in the camera. Since the existence of algorithms cannot satisfy the good accuracy on complex background including illumination change and dynamic objects, we have put forward the concept of Common Vector Approach (CVA) as a new idea for background modelling. Effectiveness of proposed method is presented based on the experiments on popular Wallflower dataset. The obtained visual outputs are compared with well-known methods based on the subjective and objective criteria. From the overall evaluation, we can note the proposed method is not only exhibit successful foreground detection results, but also promises an effective and efficient system for background modelling.

Keywords— Common Vector Approach, Background Modelling, Foreground Detection, Moving Object Detection, Change Detection.

I. INTRODUCTION

Background subtraction, determining changes in the sequence of images, is an important and painful task in computer vision. One key problem in background detection is coping with dynamic backgrounds, which involve shadows, highlights, waving trees, camera jitter, camouflage, fountains and similar movements. The key idea is deriving a model that comprises the rich information about processed scene and taking difference between the model and current image in order to yield the foreground, which is usually called as change detection. Although utilizing this idea is convenient for static background, but for dynamic backgrounds, it is not easy applicable and promising.

Until now, various methodologies are applied to alleviate problems encountered from dynamic backgrounds. The proposed methods can grouped in two ways; pixel or block based approaches. While in pixel approaches, a model is constructed for each pixel by taking the history of them, in other side, in block based approaches, the contribution of neighbour pixels are taking into account in case of modelling the background.

A crowded set of algorithms have been utilized to demonstrate satisfactory results for non-stationary background. A survey is presented by Bouwman for revealing the performance of subspace based background learning methods [1]. The impact of Principal Component Analysis (PCA) for background learning is firstly investigated in the work of Oliver et. al [2]. They applied the concept of PCA on a model of the probability distribution function of the background. Since the PCA works based on the least square estimation as sensitive to outlier, an alternative approach was developed by Torre and Block. It is called as Robust Principal Component Analysis (RPCA) [3]. Comparing with PCA and RPCA, it should be noted that effects of outliers are suppressed in case of linear based optimization when compared with nonlinear based optimization as utilized in PCA. Inspiring from the theory of work performed by Torre and Block, some variants of RPCA [4] have been developed and utilized for subspace based background learning. With a different idea, the Independent Component Analysis has been attempted with a purpose of background modelling [5]. The aim is obtaining the background model \(Y = WX_\tau\), where \(W\) and \(X_\tau\) denote the de-mixing and mixing matrices, respectively. \(X_\tau\) contains background and foreground images. The size of \(X_\tau\) is \(2xK\) as \(K\) are stored in vector format. Yet another method is Gaussian model based background modelling, which was proposed by Wren et. al in order to tracking person body, named as Pfiffer [6]. In referred work, a 2-D model based on the Maximum Posteriori Probability (MAP) was introduced for detecting and tracking human body. By focusing the changes in the region of interest (ROI) a blob model is proceeded to reveal the person body. Moreover, a comprehensive survey is available in study performed by Bouwman [7].
The capacity of each method is limited when utilized to overcome challenges caused from dynamic backgrounds. For this reason, we have proposed a new nonparametric and subspace based background modelling technique, which relies on the concept of common vector approach. The ability of Common Vector Approach (CVA) [8] for background subtraction is firstly analysed in this work. The proposed background subtraction system involves two stages; (i) the background modelling by using training images and (ii) detecting foreground objects in test image sequence. To evaluate the system performance, an experiment is conducted on well-known Microsoft’s Wallflower dataset [9, 10]. The obtained good visual and statistical results implies that the CVA can be applied for background modelling and change detection.

The rest of the paper is arranged as follows. In section 2, the CVA and its application to background modelling is presented. In section 3, the experimental results and performance comparison with well-known methods is carried out. Finally, a conclusion is touched.

II. CVA WITH APPLICATION TO BACKGROUND SUBTRACTION

CVA is a popular subspace based classification algorithm as applied for face recognition [11], spam classification [12], image denoising [13] and edge detection [14] tasks. The motivation of CVA is inspired from theory behind the PCA. While in PCA, the data is recovered by using eigenvectors corresponding to largest eigenvalues, but it has been emphasized that using null space of data gives more impressive accuracy in case of classification [8]. Based on the this fact, CVA algorithm has been put forward by authors of study in [8, 15, 16]. Specifically, by using CVA algorithm, a frame is represented with two components, which are common and difference as shown in Eq. (1). There are two cases in CVA algorithm as sufficient and insufficient data cases. If the number of vectors is less than dimension vectors, then it is called as insufficient data case, otherwise, it is sufficient data case. In case of insufficient data case, common and difference frames can be calculated by using the Gram Schmidt procedure.

In this study, the motivation under the CVA algorithm is adopted for background modelling. The key point of algorithm is encapsulating background information of different frames in order to obtain a single and meaningful background frame. Likewise to PCA, each frame is converted in to vector format.

Assuming that we have given \( n \) samples \((a_1, a_2, \ldots, a_n)\) and each frame in 1-D. With CVA algorithm, it is accepted that a given frame \( a_i \) can be separated into two parts as common and difference frame, which is denoted in Eq. (1).

\[
a_k = a_{\text{com}} + a_{\text{diff}}
\]  

(1) Where the \( a_{\text{com}} \) and \( a_{\text{diff}} \) refers to common and difference frames, respectively. In order to obtain orthogonal and orthonormal basis, the concept of Gram Schmidt is carried out on given vector set \((a_1, a_2, \ldots, a_n)\). As a first stage, the selected reference frame is subtracted from remain vectors as shown in Eq. (2). In this study, the first frame \((k = 1)\) is considered as reference frame for the sake of simplicity.

\[
d_i = a_i - a_1
\]

\[
d_2 = a_i - a_2
\]

\[
\vdots
\]

\[
d_{n-1} = a_i - a_{n-1}
\]

(2) From the combination of difference vectors, a matrix \( M = \{d_1, d_2, \ldots, d_{n-1}\} \) is obtained. The next stage is computing the orthonormal and orthogonal vectors with the idea of Gram-Schmidt procedure which is shown in Eq. (3) and Eq. (4).

\[
v_i = d_i \quad \text{and} \quad u_i = \frac{v_i}{|v_i|}
\]

(3)

\[
v_i = d_i \sum_{j=1}^{i-1} \langle d_j, u_j \rangle u_j \quad \text{and} \quad u_i = \frac{v_i}{|v_i|} \quad i = 1, \ldots, n-1
\]

(4)

Where, \( \langle d_i, u_j \rangle \) refers to dot product of two vectors and \(|v_i|\) denotes the \( l_2 \) norm of each vector. Each vector is normalized by dividing with their \( l_2 \) norm. At the end of Gram-Schmidt orthogonalization procedure the \((u_1, u_2, \ldots, u_{n-1})\) orthonormal and orthogonal \((v_1, v_2, \ldots, v_{n-1})\) sets are obtained to yield difference frame.

(3) Once the orthonormal sets are obtained, the difference frame is determined as given in the below formula. Specifically, the selected reference frame is projected on orthonormal vectors and summed up to obtain the difference frame. In this study, the first frame is taken as reference, and \( k = 1 \).

\[
a_{k, \text{diff}} = \langle a_1, u_1 \rangle u_1 + \langle a_1, u_2 \rangle u_2 + \ldots + \langle a_1, u_{n-1} \rangle u_{n-1}
\]

(4) As a result, the common vector \( a_{\text{com}} \) is derived by subtracting the \( a_{k, \text{diff}} \) from \( a_k \).

\[
a_{\text{com}} = a_k - a_{k, \text{diff}}
\]

(5)
As an improvement on CVA, a low noise value between 0-1 is injected to each difference subspace in Eq. 2 in terms of making high correlated data as low correlated form. The reason of making data low correlated is explained with idea that if the data is highly correlated then the rank becomes smaller than 2. As a result of small rank value, the obtained common vector does not become meaningful to eye. With this way, a background model with training data set is constructed as common frame refers to background and difference frame indicates foreground.

The motivation behind the CVA based background modelling is exhibited in Fig. 1. As we can observe from the Fig. 1, there are two components of a frame as:

1. first component provided the common frame of training set, which refers to obtained background model.
2. other component denotes the difference frame that exhibits details including moving objects and changes of training set.

From the Fig. 1, the ability of CVA for change detection can be observed clearly. Inspired from this fact, we have utilized the CVA algorithm for background modelling and change detection.

In case of foreground extraction, the common vector of processed test frame is computed as projecting the test frame onto the orthonormal basis generated by Gram-Schmit procedure [15]. As a first stage, the difference vectors corresponding to the test frame is obtained with Eq. 6.

\[ t_{\text{diff}} = \{t_{u_1}u_1 + t_{u_2}u_2 + \ldots + t_{u_n}u_n\} \]  

Once the difference vector is subtracted from the test vector, the common vector of processed test frame is determined as shown in Eq. 7.

\[ t_{\text{com}} = t - t_{\text{diff}} \]  

The difference between the two common vectors is considered in terms of observing the foreground regions.

\[ \forall (i, j), I(i, j) = \begin{cases} 1 & \text{abs}(t_{\text{com}} - t_{\text{diff}}) > \text{threshold} \\ 0 & \text{otherwise} \end{cases} \]  

As indicated in Eq. 7, for each pixel location \( \forall (i, j) \), if the absolute difference is greater than a fixed threshold value, then foreground mask is marked as 1, otherwise marked as 0. However, taking the absolute difference for Moved Object, Light Switch, Camouflage videos, produce a lot of erroneous pixels in foreground mask. To overcome this, only difference of two common vectors is put into the thresholding procedure. The utilized threshold value for each video are predetermined as follows; 0.1 for Camouflage, Bootstrap, Light Switch, Waving Trees, 0.2 for Foreground Aperture and 0.3 for Time Of Day and Moved Object video, respectively.

After thresholding procedure, it has been observed that some morphological procedure is greatly required to obtain best results. For this purpose, firstly, a 5x5 median filter is applied on the binary foreground mask. Then, the connected components having size of less than 20, are considered as ghosts and ignored by applying the area open morphological operator. To close the holes in binary region, the morphological closing procedure is performed with disk structural element having size of 5 and binary holes are filled with morphological filling operator. As a last step, morphological opening with disk structural element having size of 5 is performed to mitigate the effect of closing operator.

III. PERFORMANCE EVALUATION

A. Dataset

To judge the performance proposed method, some experimental are conducted on popular Wallflower Dataset. Technically Wallflower dataset [8] provides different classes of about dynamic backgrounds which are Moved Object, Time of Day, Light Switch, Waving Trees, Camouflage, Bootstrapping and Foreground Aperture. Until now, various methods have been made experimental on this dataset. The priory specified training and test images with their ground truth [10] are utilized to obtain subjective and objective results.

B. Subjective Results

In order to comment the obtained results, we have compared the produced results with other ones. For this purpose, the subjective outputs are presented on Table 2. Specifically, the visual results that are presented in the study of Bouwman [1] are considered as reference in case of performance comparison. For a benchmark comparison, the obtained visual results are compared with state of popular subspace and other methods, which are given as Single Gaussian (SG) [6], Mixture of Gaussian (MOG) [17], Kernel Density Estimation (KDE) [18], Subspace Learning PCA (SL-PCA) [19], Subspace Learning ICA (SL-PCA), Subspace Learning ICA (SL-PCA) [20], Subspace Learning via Incremental Non Negative Matrix Factorization (SL-INMF) [21] and Subspace Learning via Incremental Rank-(R1, R2, R3) Tensor (SL-IRT) [22].

The all of visual results are exhibited in Table 1. The first column indicates the method’s name, the rest of columns
Table 1. Subjective Results on the Wallflower dataset

<table>
<thead>
<tr>
<th>Method</th>
<th>Moved Objects</th>
<th>Time of Day</th>
<th>Light Switch</th>
<th>Waving Trees</th>
<th>Camouflage</th>
<th>Boot-strap</th>
<th>Foreg. Aperture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test image</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground truth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG Wren et al.</td>
<td>FN</td>
<td>0</td>
<td>949</td>
<td>1857</td>
<td>3110</td>
<td>4101</td>
<td>2215</td>
</tr>
<tr>
<td>MOG Stauffer et al.</td>
<td>FN</td>
<td>0</td>
<td>1008</td>
<td>1633</td>
<td>1323</td>
<td>398</td>
<td>1874</td>
</tr>
<tr>
<td>KDE Elgammal et al.</td>
<td>FN</td>
<td>0</td>
<td>1298</td>
<td>760</td>
<td>170</td>
<td>238</td>
<td>1755</td>
</tr>
<tr>
<td>SL-PCA Oliver et al.</td>
<td>FN</td>
<td>0</td>
<td>879</td>
<td>962</td>
<td>1027</td>
<td>350</td>
<td>304</td>
</tr>
<tr>
<td>SL-ICA Tsai and Lai</td>
<td>FN</td>
<td>0</td>
<td>1199</td>
<td>1557</td>
<td>3372</td>
<td>3054</td>
<td>2560</td>
</tr>
<tr>
<td>SL-INMF Bucak et al.</td>
<td>FN</td>
<td>0</td>
<td>724</td>
<td>1593</td>
<td>3317</td>
<td>6626</td>
<td>1401</td>
</tr>
<tr>
<td>SL-IRT Li et al.</td>
<td>FN</td>
<td>0</td>
<td>1282</td>
<td>2822</td>
<td>4525</td>
<td>1491</td>
<td>1734</td>
</tr>
<tr>
<td>CVA Proposed</td>
<td>FP</td>
<td>0</td>
<td>1012</td>
<td>946</td>
<td>766</td>
<td>708</td>
<td>982</td>
</tr>
</tbody>
</table>

Table 2. Objective Performance Evaluation on the Wallflower dataset

<table>
<thead>
<tr>
<th>Method</th>
<th>Error</th>
<th>Moved Object</th>
<th>Time of Day</th>
<th>Light Switch</th>
<th>Waving Trees</th>
<th>Camouflage</th>
<th>Bootstrap</th>
<th>Foreground Aperture</th>
<th>Total Errors</th>
<th>TE without LS</th>
<th>TE without C</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG Wren et al.</td>
<td>FN</td>
<td>0</td>
<td>949</td>
<td>1857</td>
<td>3110</td>
<td>4101</td>
<td>2215</td>
<td>1290</td>
<td>35133</td>
<td>18153</td>
<td>28992</td>
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<tr>
<td>MOG Stauffer et al.</td>
<td>FN</td>
<td>0</td>
<td>1008</td>
<td>1633</td>
<td>1323</td>
<td>398</td>
<td>1874</td>
<td>530</td>
<td>27053</td>
<td>11251</td>
<td>23557</td>
</tr>
<tr>
<td>KDE Elgammal et al.</td>
<td>FN</td>
<td>0</td>
<td>1298</td>
<td>760</td>
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<td>238</td>
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<td>624</td>
<td>26450</td>
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<td>22175</td>
</tr>
<tr>
<td>SL-PCA Oliver et al.</td>
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<td>879</td>
<td>962</td>
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<td>350</td>
<td>304</td>
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<td>17677</td>
<td>16353</td>
<td>15779</td>
</tr>
<tr>
<td>SL-ICA Tsai and Lai</td>
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<td>2721</td>
<td>15308</td>
<td>13541</td>
<td>12211</td>
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<tr>
<td>SL-INMF Bucak et al.</td>
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<td>724</td>
<td>1593</td>
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<td>6626</td>
<td>1401</td>
<td>3412</td>
<td>19098</td>
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<td>12238</td>
</tr>
<tr>
<td>SL-IRT Li et al.</td>
<td>FN</td>
<td>0</td>
<td>1282</td>
<td>2822</td>
<td>4525</td>
<td>1491</td>
<td>1734</td>
<td>2438</td>
<td>17053</td>
<td>13842</td>
<td>15448</td>
</tr>
<tr>
<td>CVA Proposed</td>
<td>FP</td>
<td>0</td>
<td>1012</td>
<td>946</td>
<td>766</td>
<td>708</td>
<td>982</td>
<td>2537</td>
<td>7891</td>
<td>6625</td>
<td>7175</td>
</tr>
</tbody>
</table>
show the performance of each aforementioned methods. Also, the first row denotes the processed image, second row indicates the ground truth related to given image and other rows show visual result generated by each method.

At a first glance, we can observe that similar outputs are obtained from each method. Upon inspecting results, one can emphasize that probabilistic based methods including MOG and KDE produce similar results in terms of foreground region detection. The results of KDE and MOG are superior than SG, since background modelling with single Gaussian is a short-side in term of complex background. Again, we can emphasize that SG, MOG and KDE are sensitive illumination changes because of working on historical probability of each pixel.

On the other side, the subspace based methods are more robust to illumination and complex background changes. By examining results of PCA, ICA, INMF and IRT, it can be seen that the visuals result of IRT are not converged to ground truth as some objects are disappeared in foreground mask. Moreover, although the PCA method exhibits good results in case of Time of Day, Light Switch, Waving Trees, Camouflage, Foreground Aperture, but some erroneous pixels are obtained for Moved Objects and Bootstrap videos. Furthermore, visual outputs of ICA and INMF are similar to each other, however, the performance of ICA is more dominant for Camouflage and Bootstrap videos.

Finally, we can observe that CVA and PCA generate closest results, however, the PCA method fails in case of indoor crowded scene (bootstrap). Also, one can note that the proposed method can perfectly model the clean background in case of illumination changes, crowded scenes and other complex backgrounds. As a result, good foreground mask are determined for all videos.

C. Objective Results

In addition to subjective evaluation, the objective results for each method is determined with respect to statistical metrics, called false positive (FP) and false negative (FN). While the FP indicates the pixel marked as foreground in processed image but it is background in ground truth image, conversely the FN refers to the pixel marked as background in processed image but it is foreground in ground truth image. If a pixel is marked as 1 in processed image, but it is 0 in ground truth image, then the count of FP is incremented by 1. Similarly, If a pixel is marked as 0 in processed image, but it is 1 in ground truth image, then the count of FN is incremented by 1. By combining these error values, the Total Error (TE) metric is computed as a sum of FP and FN. The lower value of error value denotes the best performance in the concept of foreground segmentation. Also, the Total Errors without light switch (TE without LS) and Total Errors without Camouflage switch (TE without Camouflage) are presented on the last columns of Table 2.

The Table 2 summarizes all of the objective results for aforementioned background modelling methods. As we can see that the performance MOG and KDE are close to each other and show better performance than SG method. The performance of MOG and KDE are better when the light switch video excluded, but worse in case of TE metric. Comparing the PCA, ICA, INMF and IRT, one can observe that the performance of ICA is dominant in case of all metrics. On the other side, we can find that the CMA method combining with the basic post processing procedure show favourable results in terms of all metrics.

IV. Conclusions

In the present, a new idea is introduced for background modelling and foreground detection in a given video. Through experiments on real and complex videos, we have observed that the proposed method can efficiently detect the changes in a given set of images. The performance of proposed are compared with state of algorithms including SG, MOG, KDE, PCA, ICA, IRT and INMF and commented with respect to the some objective and subjective measures. The obtained superior results indicate that it is appropriate to use the CVA method for background modelling. Also, we can emphasize that an intelligent post processing procedure is vitally needed in order to accurate foreground detection and segmentation.

REFERENCES


A Literature Review of Wind Speed Prediction Techniques

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Abstract—With the developing technology of electrical energy use is increasing, and this increase in the search for new sources of electrical energy generation brings. Fossil-based increasingly depletion of resources and environmental pollution lead to these fuels from renewable energy resources become more important with each passing day brings. Today, wind energy, electricity generation of approximately 70 countries around the world in an area that has become a benefit. There are different prediction techniques useful to estimate the uncertainty of the wind. These prediction techniques are used to estimate wind power generation capacity for the system. This study supplies grip on the first estimation methods, incorporated with wind speed and power, established on numeric weather prediction (NWP), statistical approaches, ARIMA models, artificial neural network (ANN) and hybrid techniques over different time-periods. This study will be helpful for the new surveyors who are going to work in this area. This study will be useful to the wind generations attendants to understand about the present wind forecasting model capacities and will give an opinion to forecast the wind speed at their exclusive wind energy systems.

Keywords—neural networks, fuzzy logic, wind speed prediction, auto-regressive moving average, auto-regressive integrated moving average

I. INTRODUCTION

Determine the level of development of the country of primary importance criteria is the use of electrical energy. With the developing technology of electrical energy use is increasing, and this increase in the search for new sources of electrical energy generation brings. Fossil-based increasingly depletion of resources and environmental pollution lead to these fuels from renewable energy resources become more important with each passing day brings. Today, wind energy, electricity generation of approximately 70 countries around the world in an area that has become a benefit. In recent years, instead of fossil fuels in Turkey preferred wind energy, most investment in electricity generation is among the areas. In order to generate electricity from the wind, The potential of that region must be determined. To establish the potential of the wind energy, The wind speed per hour and direction information in the area, should be measured for at least one year. The resulting analysis of these records gives important ideas about whether to establish a wind farm in the region. Even in the planning large and powerful wind power plants, established in a long period it is necessary to comprehensive retrospective analysis coverly long years. In this study, by researching the publication of the researchers, tried different speed estimation techniques, the nearest wind speed estimation methods will be determined.

A. Statistical Techniques

Short-term wind speed forecasting experimental stages, Statistical techniques are preferred because of low cost and can be easily modeled. but due to the increase in the estimated error rate with increasing duration of medium and long-term wind speed prediction it is not preferred. Statistical methods contain the auto-regressive moving average (ARMA), auto-regressive integrated moving average (ARIMA), curve fitting, Bayesian model, time series models.

ARIMA techniques can effectively be used to forecast attitude, of a time series from past data exclusively ARMA models are a integrated of Auto-Regression (AR) and Moving Average (MA) models and a particular state of Auto-regressive Integrated Moving Average (ARIMA) models. Auto-Regression Moving Average (ARMA) models are the most preferred type in the time-series situated approach to forecast futurity data of wind speed.

Auto-Regression Integrated Moving-Average (ARIMA) techniques are the generalized forms of ARMA models. This model generally includes three components, which are autoregressive, integrated and moving average. ARIMA model is data independent.

The statistical time series techniques are mostly preferred at short-term estimations. Typical time series models are advanced established on historical data. They are easy to model and able to provide timely forecasting. Time series is a set of successive data points of a parameter that are generally spaced at same time periods. A time-series forecasting sample usages the previous cases of the parameter to establish its forward data. One of the basic characteristics of Bayesian statistics rests on the fact that, opposite to the frequentist approach, the possibilities associated to a variable in a given results are not taken as how many times, or how frequently (their frequency) they are observed.

Maatallah et al. [8] in 2015 for a three year data obtained from two different sites from 1 to 24 hours wind speed forecasting developed approach hammerstein model adapted for multilayer neural network and comparing it with ARIMA. Kulkarni et al. [10] The curve fitting, artificial neural networks, export the periodic function estimation and Autoregressive Integrated moving average wind speed estimation methods were compared in 2008.
Liu et al. [31] wind speed forecasting EMD-ANN hybrid method compared with the model of auto-regressive moving integrated average (ARIMA) in 2012. Palomares-Salas et al. [29] used estimating wind speed ann and arima methods compared detailed in 2014.

Kavasseri and Seetharaman [38] in 2009 North Dakota wind speed obtained from the four regions according to the records of the fractional ARIMA, or f-ARIMA models using the 24-hour and 48-hour wind speed forecasting of before. S. Salcedo-Sanz et al. [48] meteorological prediction of physical model in 2014 by using variables, a Coral Reef Optimization algorithm (SAK) and Extreme learning machine (ELM) based on a newer approach to short-term wind speed estimation. Kiplangat et al. [49] in 2016 wind speed variation and to predict time series modeling, the auto-regressive (AR) and f-ARIMA models were compared. S. Salcedo-Sanz et al. [45] prediction of meteorological physical model by using variables, a Coral Reef Optimization algorithm (SAK) and Extreme learning machine (ELM) based on a newer touch to very short periods wind speed prediction in 2014.

Miranda and Dunn [55] to characterize the wind resource in 2006 one hour before using a Bayesian approach it focuses on wind speed forecast. Liu et al. [58] spectral clustering (SC) in their study in 2015 and echo state Networks resilient were studied based on a wind speed estimation methods. Jiang et al. [65] studied the work they did short time periods wind speed for Bayes estimated based on modeling of time series analysis and structural breaksin 2013. Wang et al. [66] using wind data of the four sites in China in their study in 2016, and the wind speed probability distribution and methods of estimation parameters for these models (commonly used methods and stochastic heuristic optimization algorithm) to popular parametric and non-they compared parametric models. Skittides and Früher [67] In a study conducted in 2014 in Edinburgh due to a site from the Meteorological Office from 2008 to 2009 wind speed and direction data to Principal Component Analysis (PCA), based on tested new statistics for the data from the applied wind estimator 2010. D'Amico et al. [70] used the semi-Markov model to estimate wind speed and power to be generated by the wind turbine in 2014.

Koivistio et al. [77] in a study conducted in 2016 wind speed forecast is bound to the intervention Vector-Autoregressive-To-Anything (VARTA) and montecarlo simulation. Cassola and Burlando [77] in 2012 to fall and the wind speed estimated wind farm for numerical weather prediction (NWP) method of kalman filter (KF) applied with.

B. Fuzzy System Based Models

Fuzzy logic is an ambiguous world's gray, discreet help to computers to produce pictures of machine intelligence. Fuzzy logic modeling of human thinking concept in general format. Fuzzy logic is different from classical mathematical method, is that it allows the qualitative lack of deterministic and identifications. Uncertainties can be expressed as mathematical modeling of complex systems fuzzy logic is considered the biggest convenience. Fuzzy logic in the concept of a member of a cluster is determined by whether or not a member of the membership functions. Used fuzzy logic inference methods with this concept by using the events as an attempt is made to make comment. Onat and Ersoz [5] in 2010 using five-layered adaptive neuro-fuzzy inference system (ANFIS) for the three regions of Turkey's were able to identify the relationship between wind speed and other climatic variables. Petković [21] was used to Adaptive neuro-fuzzy inference system (ANFIS) estimate wind speed the probability density distribution in 2015. Damousis et al. [24] in 2004 made an estimated wind speed for wind parks with fuzzy method. Monfareda et al. [30] compared with a different strategy wind speed prediction methods artificial neural networks (ANN) with fuzzy logic in 2009. Shammari et al. [57] a study conducted in 2014 used adaptive neuro-fuzzy inference system (ANFIS) wind speed prediction for wind energy production systems. Shammari et al. [61] in 2014 to predict the wind speed probability density distribution, adaptive neuro-fuzzy inference frame (ANFIS) was used. Shammari et al. [62] In a study conducted in 2015, wind speed and annual probability density distributions to estimate adaptive neuro-fuzzy inference system (ANFIS) were used. Nikolić et al. [68] their study in 2015 on the strength and to predict the wind speed on ANFIS (adaptive neuro-fuzzy inference system) were involved in the implementation. to provide statistical analysis of the RMS (root mean square error), determination (R2) and Pearson's correlation coefficient (r) coefficients were used. Shuang An et al. [40] fuzzy partition fuzzy regression based on fuzzy rough sets consisting of forecast values a regression algorithm explained in 2014. Mohandes et al. [43] used to estimate wind velocities at different heights by adaptive neuro-fuzzy inference system (ANFIS) in 2011. Al-Shammari et al. [44] used adaptive neuro-fuzzy inference system (ANFIS) to estimate the wind speed to design wind turbines for wind farms in 2015. Sun et al. [46] used a fuzzy copula model for wind speed forecasting in 2016. Petković et al. [47] in a study conducted in 2015 were used adaptive neuro-fuzzy inference system (ANFIS) to estimate the annual wind speed probability density distribution function.

C. Artificial Neural Networks

Artificial neural networks (ANN) is to derive new information and learning ways in which the characteristics of the human brain-like capabilities to create new knowledge and the possibility of discovering the computerized system developed with the aim to automatically perform without any help. Artificial neural networks; Inspired by the human brain, the mathematical modeling has emerged as a result of the learning process pursuit. Abdel-Aal et al. [1] Average hourly wind speed estimates for 1 hour abductive various models next year in May during 1994-2005 over Dhahran, Saudi Arabia has been developed using wind speed data in 2009. Amjadi and Theocharis in 2006 [4] using locally recurrent neural networks (LNN) estimation long time periods wind power and speed for a wind farm. Li and Shi [11] North Dakota gained two observation House hour average wind speeds of 3 different neural networks (typical neural networks, Adaptive Linear
According to previously established analytical method to vector regression (SVR) Weibull distribution function 2014 polynomial and wind speed forecast model with neural networks and support and D. (NN) models decomposit to compare wind forecasting using the empirical mode used data included from a wind farm in Inner spatial dimensions using.


Zheng et al. [34] photovoltaic and wind power generation for the last 10 years and the estimate the methods of statistical and artificial intelligence were examined in 2011. Charhate et al. [48] in the Arabian Sea and the Western Indian coast around wind data obtained from the measurements five nautical point made from, genetic programming (GP) to assess the wind-wave affair and artificial neural network (ANN) have used two pure non-linear approach in 2008. Agrawal and Sandhu [51] in their study 2016 Artificial neural networks-based Annual Auto Regressive (ANNYAR) model that extends from 6 to 96 hours effects of wind forecast most effective parameter and time horizon (TH) annual data set needed to figure out a series in and around fields 'VABB airport Mumbai is included for the purpose of Data Modeling and analysis. Chen and Yu [51] In a study conducted in 2014, unscented Kalman filter (UKF) full wind speed short-term forecast on the SVR-UKF method with artificial neural networks (ANN) method was compared to Noorollahi et al. [64] 2016 In this study, three wind monitoring stations in Iran (Woss) neural networks of the one-hour time interval obtained by wind speed data artificial neural networks (ANN) have made wind speed estimated in both temporal and spatial dimensions using. Shouxiang Wang et al. [51] in 2016 used data included from a wind farm in Inner Mongolia China to compare wind forecasting using the empirical mode decomposition and GE-BP neural network based on wind speed estimation method and wavelet wind speed of neural Networks (NN) models

D. Support Vector Machine

Support vector machines (SVM) are a series of related supervised learning methods used for classification and regression. Sreelakshmi and Kumar [12] in 2008 short term wind speed forecast model with neural networks and support vector machine models were compared. Petković et al. [23] in 2014 polynomial and Radial basis function (RBF) support vector regression (SVR) Weibull distribution function according to previously established analytical method to estimate the two parameters) have imposed as a kernel function. Mohammadi et al. [56] in China 2015 based on a newer model is presented to estimate the wind energy density. The validity of the ELM (extreme learning machine) model SVM (Support Vector Machine), ANN (Artificial Neural Networks) and GP (Genetic Programming) is validated by comparing predictions with techniques. All approaches compared with the results estimated by the wind forces calculated using measured data. Chen and Yu [59] In a study conducted in 2014, unscented Kalman filter (UKF) full wind speed short-term forecast on the SVR-UKF method with artificial neural networks (ANN) method was compared to. Yuan et al. [60] to predict the wind power briefly in a study conducted in 2015, based on least squares a hybrid model (LSSVM-GSA Back Propagation (BP) neural network and support vector machine (SVM) they compared the model, Jian-Zhou et al. [63] in 2015 Wavelet Packet Transform (WPT) series with several different frequencies are used to parse the wind speed range. Simulated annealing (PSOS A) based on a Least Squares Support Vector Machines (LSSVM), which was set up by a particle swarm optimization parameters, this series is built to model. Suitably the model, the input phase area again (PSR) was determined. To support the influence of the propounded model, Gansu Province, Northwest China, four wind farms was used as a condition research the fresh average wind speed set. Tagliaferri, et al. [63] artificial neural networks (ANN) and support vector machines (SVM) based wind speed estimation techniques were compared in 2015. Kong et al. [63] using the reduced support vector machine (RSVM) for the Real time wind power plant data wind speed prediction in 2015.

E. Hybrid Techniques

Hybrid techniques integration of different approaches is referred to as a hybrid approach, usually produce good wind speed prediction results compared to singular techniques. The object of hybrid techniques is utilizing from the superiors of each method and acquires a globally optimum prediction accomplishment. Since the data included in the separate forecasting method is constricted, hybrid technique can maximize the valid information, integrate separate model instructions and make the best use of the advantages of multiple forecasting techniques thus improving the estimation accuracy. There are the hybrid techniques integration different approaches such as mixing physical and statistical approaches or combine short-term and medium-term models. Many types of hybrid techniques were utilized to estimate wind speed. The types of combinations can be:

- Integration of physical and artificial intelligence approaches
- Integration of statistical and artificial intelligence approaches
- Integration of alternative artificial intelligence models

short time periods and medium time periods wind speed for 5 hours up to 1 hour intervals in 2016. Wei Sun and MLP (multi Layer Perceptron) neural networks were recommended for accurate predictions, GA (Genetic Algorithm) and Ensemble Empirical Mode Decomposition (FEEMD), MEA (Mind and the Kalman Filter (KF) compared single and hybrid forms in 2012. Shukur and Lee [39] obtained wind speed data from Iraq and Malaysia, used based on the ARIMA model a hybrid of MF-ANN model to wind speed estimation in 2015. Wang, [50] Support vector regression (SVR), machine learning technique (MLT), seasonal index adjustment (SIA) and Elman recurrent networks, support vector machine and hybrid techniques are employed by researchers about the publications. As a result of the publications, while short term forecasting fuzzy logic and statistical techniques were successfully. Long-term wind speed estimation in support vector machines (SVM), neural networks (NN) and hybrid techniques predictions were more successfully. It is expected to give more reliable results by developing wind speed estimation methods in future

II. CONCLUSIONS

At the present time the electric energy with renewable energy sources for the production of electricity from wind power has increased. The share in total electricity supply is increasing. Wind speed estimation methods have been developed to determine the potential of wind. First of all wind prediction systems have been developed in order to determine efficient wind energy potential. In this article we have searched wind speed prediction of statistical techniques, fuzzy logic, neural networks, support vector machine and hybrid techniques are explored by researchers about the publications. As a result of the publications, while short term forecasting fuzzy logic and statistical techniques were successfully. Long-term wind speed estimation in support vector machines (SVM), neural networks (NN) and hybrid techniques predictions were more successfully. It is expected to give more reliable results by developing wind speed estimation methods in future.

REFERENCES


A note on background subtraction by utilizing a new tensor approach

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Abstract— This study deals with determining the foreground region by background subtraction based on a new tensor decomposition method. With this aim, the concept of Common Matrix Approach (CMA) is utilized with a purpose of background modelling. The performance of proposed method is validated by making experiments on real videos provided by Wallflower dataset. The obtained results are compared with well-known methods based on subjective on objective evaluation measures. The obtained good results indicate that using the CMA algorithm for background modelling is a simple and effective technique in terms computational cost and implementation. As an eventual result, we have observed that the superior results are determined on complex backgrounds including dynamic objects and illumination variation in image sets.

Keywords— Common Matrix Approach, Background Modelling, Foreground Detection, Moving Object Detection, Change Detection.

I. INTRODUCTION

Foreground detection is the principal interest topic of computer vision based applications such as intelligent visual surveillance, intelligent visual observation of animals and insects, optical motion capture, human-machine interaction, content based video coding, etc. The most extensively utilized areas can be given as road surveillance airplane surveillance, maritime surveillance, boats and store surveillance systems, in where “people” is the main point of interest [1].

Major challenges associated with background subtraction can be noted as shadow, waving trees, foundations, intensity changes and camera jitter, which are called as dynamic backgrounds. Although a perfect solution has not been proposed to cope with these problems, but an affirmed method should be capable to alleviate all dynamic problems. The general idea is actuating a mathematical model to represent all image sequences of the processed background scene with a rich information one. Once the background model obtained, the difference between the test frame and model is considered as foreground.

Numerous algorithms are proposed for background subtraction with a statistical or mathematical theory. By taking the handling strategy of images, the categorization of them can be grouped in two ways as 2-D based methods or tensor based methods. Technically, in the concept of 2-D based methods, each MxN frame is converted into vector format and a 2-D matrix is constructed with (M.N)xK size as K denotes number of frames in training set. Conversely, in tensor based one (3-D), a set of 2-D frames are combined and background is modelled through the tensor without converting frame into vector format. The 2-D based methods have disadvantages when compared with the tensor one. Specifically, in vector based methods the spatial information behind the neighbourhood pixels are neglected as all columns in a frame are connected as back to back in case of converting frame into vector format.

Various tensor decomposition based methods have been illustrated in research area of background subtraction. The Diffusion Bases (DB) [2] methodology has been adopted by decomposing 3-D data into 2-D plane, which denotes the learnt background model. The capability of incremental tensor based background modelling [3] has been investigated with application for foreground segmentation and tracking. Another alternative method versus Principal Component Analysis (PCA) has been utilized by applying the concept of Locality Preserving Projections (LPP) [4], which is called as LPPP. An optimal rank-(R1, R2, ..., Rn) tensor decomposition [5] model has been proposed in order to the high-dimensional tensor to low dimensional as sparse irregular patterns. Also, the Tensor Singular Value Decomposition on Fourier Domain has been analyzed for multilinear data completion and denoising, which is named as t-SVD [6].

Because of different challenges in the concept of background dataset, proposed methods do not meet all expectations. With this aim, a new tensor based background learning and change detection algorithm is presented in order to successful discrimination of foreground and background. Specifically, the theory of Common Matrix Approach (CMA)
is applied to decompose 3D dimensional data (tensor) [7]. In case of orthogonal decomposition, the motivation of Gram-
Schmidt orthogonalization is adopted. After projection stage, a common matrix that refers to obtained background model is
determined. To report the statistical and visual results, the test
stage is conducted on Wallflower dataset [8, 9]. By comparing the statistical results with some of other tensor
based approaches, one can observe that the proposed method
provides impressive and dominant results.

The remain part of paper is designed as follows. In section 2
the CMA and its application to foreground extraction is
presented. In section 3, the obtained objective and subjective results are compared with other tensor based approaches.
Finally, a conclusion is touched.

II. CMA WITH APPLICATION TO BACKGROUND SUBTRACTION

The CMA algorithm is an extended form of Common
Vector Approach, which is a subspace based method and
utilized for face recognition [10], spam classification [11],
image denoising [12] and edge detection [13] tasks. However
the ability of CMA for background modelling has not been
realized in literature of computer vision. In case of CVA the
data is handled in vector format as a 2-D matrix is constituted
from training set and matrix decomposition strategy is applied,
whereas for CMA, a tensor is generated from 2-D frames.

The main idea behind the CMA is combining background
information from different frames and obtaining a single
frame, in which summarizes cues about background locations.
Assuming that we have given n sample frames 
\(S_1, S_2, \ldots, S_n\) and each frame in 2-D. In the context of CMA
a frame can be represented with common and difference frame
as shown in Eq. (1).

\[
S_k = S_{com} + S_{diff_k} \quad (1)
\]

(1) Where the \(S_{com}\) and \(S_{diff_k}\) refers to common and
difference frames, respectively. To calculate, Common
frame a tensor with 3-D size is constructed and the concept of Gram
Schmidt is applied to derive orthogonal and orthonormal basis. First of all,
difference matrices are calculated by taking a first
frame as reference. Instead of first frame, a different
frame can be chosen as reference.

\[
D_k = \begin{cases} 
S_k - S_1 \\
S_k - S_2 \\
\vdots \\
S_k - S_{n-1}
\end{cases} \quad (2)
\]

(2) Once a tensor \(T = \{ D_1, D_2, \ldots, D_{n-1} \} \) is obtained, the
Gram-Schmidt procedure is activated on elements of \( T \),
which is shown in Eq. (3) and Eq. (4).

\[
V_i = D_i \text{ and } U_i = \frac{V_i}{|V_i|} \quad (3)
\]

\[
V_i = D_i - \sum_{j=1}^{i-1} \langle D_j, U_j \rangle U_j \text{ and } U_i = \frac{V_i}{|V_i|} \quad (4)
\]

Where, \( \langle D_i, U_j \rangle \) indicates dot product of two vectors
and \( |V_i| \) denotes the Frobenious norm of each vector
Each of the orthogonal matrices \( V_i \) is divided by their
Frobenious norm to make them normalized. After Gram-
Schmidt orthogonalization procedure the orthogonal 
\( (V_1, V_2, \ldots, V_{n-1}) \) and \( (U_1, U_2, \ldots, U_{n-1}) \)
orthonormal sets are extracted to compute difference matrix.

(3) The next stage of CMA based background modelling
algorithm is computing the difference and common
matrices based upon orthonormal basis as given in the
below equation.

\[
S_{diff_k} = \{ S_k, U_1 \} + \{ S_k, U_2 \} + \ldots + \{ S_k, U_{n-1} \} U_{n-1} \quad (5)
\]

(4) Finally, subtracting the \( S_{diff_k} \) from \( S_k \) gives common
matrix for class, where \( k = 1 \)

\[
S_{com} = S_k - S_{diff_k} \quad (5)
\]

With this way, the training of set background can be
represented by a unique 2-D frame, which is named as,
common matrix. In other side, all details including noises
and outliers of training set are stored in difference matrix
\( S_{diff_k} \).

![CMA Algorithm](image)

Fig. 1. Demonstration of proposed method

To obtain meaningful common matrix a low value of random
noise is added to each difference subspaces obtained in Eq. 2.
Since the rank of data becomes smaller than 2 in case of
highly correlated data and results in not meaningful common
matrix that is undistinguishable with human eye. To overcome
this problem, a low noise value between 0-1 is injected to each
difference subspace in Eq. 2 in terms of reducing the correlation ratio among the processed images.

From the Fig. 1, we can observe that the decomposed tensor generates two components:
1. The first component reserves the common matrix of training set, which is the obtained background model.
2. The other component involves the difference matrix that refers to detail features of training set.

By using the CMA, we can see that foreground and changes are observed in difference matrix. Therefore, the strategy behind CMA provides a new way to detect moving and stable objects in a given dataset. In order to reveal the foreground objects, the common matrix of test frame (F) is determined from the projection of incoming test frame onto the orthonormal basis returned by Gram-Schmit procedure [14]. First of all, the difference matrix related to the test frame is calculated as shown in below equation.

\[ F_{\text{diff}} = \{F, U_1\} U_1 + \{F, U_2\} U_2 + \ldots + \{F, U_{(n-1)}\} U_{(n-1)} \]  

Again, the common matrix corresponding to the test frame is computed by subtracting from the difference matrix.

\[ F_{\text{con}} = F - F_{\text{diff}} \]  

In case of revealing the foreground objects the difference between the common matrix of processed video and common matrix of processed frame is taken into account.

\[ \forall (i, j), I(i, j) = \begin{cases} 1 & \text{abs}(F_{\text{con}} - S_{\text{con}}) > \text{threshold} \\ 0 & \text{otherwise} \end{cases} \]  

As shown in equation above, the difference of two common matrix presents foreground objects. In case of Moved Object and Camouflage videos, the difference of two common matrices are considered to find the foreground regions for other ones the absolute difference taken into account. The threshold value for each video are determined as follows: 0.1 for Camouflage, Bootstrap and Waving Trees, 0.2 for Foreground Aperture, Light Switch and Moved Object, and 0.3 for Time Of Day video, respectively.

To obtain the pleasing visual results, some fixed morphological operations are applied on the foreground mask. Firstly, 5x5 median filter are utilized on the binary image. The connected components with the size of less than 20, are considered as ghost are removed by area open morphological operator. Then, the morphological closing procedure is utilized with disk structural element having size of 5 and binary holes are filled with morphological filling operator. Finally, morphological opening with disk structural element having size of 5 is performed to mitigate the effect of closing operator.

III. PERFORMANCE EVALUATION

A. Dataset

The experimental stages are conducted on well-known Wallflower Dataset. Numerous methods have been utilized this dataset in order to objective and subjective performance comparison. Wallflower dataset [9] includes real-world background datasets as associated with dynamic events including Moved Object, Time of Day, Light Switch, Waving Trees, Camouflage, Bootstrapping and Foreground Aperture. In case of background modelling (obtaining Common Matrix), we have utilized prior determined train images, which are specified by authors of dataset [8]. For each video, the first 199 images are taken to learn the background frame in case of training stage.

B. Subjective Results

In the present work, a simple thresholding methodology is realized in case of revealing the binary skeleton of objects. Since the difference of two common matrix gives changes, a fixed thresholding is carried over the absolute difference. The obtained visual results are demonstrated on Table 2. To subjectively judge performance of both methods, the obtained visual results are compared with state of popular subspace and other methods, which are given as Single Gaussian (SG) [15], Mixture of Gaussian (MOG) [16], Kernel Density Estimation (KDE) [17], Subspace Learning PCA (SL-PCA) [18], Subspace Learning ICA (SL-ICA) [19], Subspace Learning via Incremental Non Negative Matrix Factorization (SL-INMF) [20] and Subspace Learning via Incremental Rank-(R1, R2, R3) Tensor (SL-IRT) [21]. For this purpose, the visual results determined in the work of Bouwman [22] are taken as ground on in case of performance comparison.

In Table 2, the first column denotes method’s name, the other columns show video’s name, respectively. Again, the first row and second row exhibit test image and related ground truth, and other rows demonstrates visual results returned from each method. From the exhibited results, we can observe that each method presents similar foreground objects in the meaning of obtained foreground skeleton. By analysing results, one can note that results of MOG and KDE are closes to each other and are dominant than SG method. The performance of SG, MOG and KDE are weakness to illumination changes due to work on historical probability of pixels. To continue, we can see that subspace based method are more robust to light changes. By comparing the PCA, ICA, INMF and IRT, we can emphasize that the result of IRT is the worst one in terms of preserving foreground skeleton. While the INMF shows good results in case of bootstrap video, but the same performance has not maintained in case of camouflage video. Moreover, the results of PCA are similar to CVA method, however, the PCA method fails in case of indoor crowded scene (bootstrap). Furthermore, the proposed method not only robust to dynamic structures but also resistance to illumination change in case of foreground detection.

C. Objective Results

In addition to subjective results, the statistical results are obtained by considering the false positive (FP) and false
### Table 1. Results on the Wallflower dataset

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Moved Objects</th>
<th>Time of Day</th>
<th>Light Switch</th>
<th>Waving Trees</th>
<th>Camouflage</th>
<th>Bootstrap</th>
<th>Foreg. Aperture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test image</td>
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<td>Ground truth</td>
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<td></td>
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<tr>
<td>SG Wren et al.</td>
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<tr>
<td>MOG Stauffer et al.</td>
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<tr>
<td>KDE Elgammal et al.</td>
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<tr>
<td>SL-PCA Oliver et al.</td>
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<tr>
<td>SL-ICA Tsai and Lai</td>
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<tr>
<td>SL-INMF Bucak et al.</td>
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<tr>
<td>SL-IRT Li et al.</td>
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<tr>
<td>CMA Proposed</td>
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</tbody>
</table>

### Table 2. Performance Evaluation on the Wallflower dataset

<table>
<thead>
<tr>
<th>Method</th>
<th>Error</th>
<th>Moved Object</th>
<th>Time of Day</th>
<th>Light Switch</th>
<th>Waving Trees</th>
<th>Camouflage</th>
<th>Bootstrap</th>
<th>Foreg. Aperture</th>
<th>Total Errors</th>
<th>TE without LS</th>
<th>TE without C</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG Wren et al.</td>
<td>FN</td>
<td>0</td>
<td>949</td>
<td>1857</td>
<td>3110</td>
<td>4101</td>
<td>2215</td>
<td>3464</td>
<td></td>
<td>35133</td>
<td>18153</td>
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<tr>
<td></td>
<td>FP</td>
<td>0</td>
<td>535</td>
<td>15123</td>
<td>357</td>
<td>2040</td>
<td>92</td>
<td>1290</td>
<td></td>
<td>27053</td>
<td>11251</td>
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<tr>
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<td></td>
<td>0</td>
<td>1008</td>
<td>1633</td>
<td>1323</td>
<td>398</td>
<td>1874</td>
<td>2442</td>
<td></td>
<td>26450</td>
<td>11537</td>
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<tr>
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<td></td>
<td>0</td>
<td>1298</td>
<td>760</td>
<td>170</td>
<td>238</td>
<td>1755</td>
<td>2413</td>
<td></td>
<td>17677</td>
<td>16353</td>
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<tr>
<td>SL-PCA Oliver et al.</td>
<td></td>
<td>0</td>
<td>879</td>
<td>962</td>
<td>1027</td>
<td>350</td>
<td>304</td>
<td>2441</td>
<td></td>
<td>15308</td>
<td>13541</td>
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<tr>
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<td></td>
<td>0</td>
<td>1199</td>
<td>1557</td>
<td>3372</td>
<td>3054</td>
<td>2560</td>
<td>2721</td>
<td></td>
<td>19098</td>
<td>17202</td>
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<td></td>
<td>0</td>
<td>724</td>
<td>1593</td>
<td>3317</td>
<td>6626</td>
<td>1401</td>
<td>3412</td>
<td></td>
<td>17053</td>
<td>13842</td>
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<tr>
<td>SL-IRT Li et al.</td>
<td></td>
<td>0</td>
<td>1282</td>
<td>2822</td>
<td>4525</td>
<td>1491</td>
<td>1734</td>
<td>2438</td>
<td></td>
<td>8218</td>
<td>7016</td>
</tr>
<tr>
<td>CMA Proposed</td>
<td></td>
<td>0</td>
<td>1017</td>
<td>882</td>
<td>26</td>
<td>172</td>
<td>929</td>
<td>2534</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
negative (FN) pixels. With this aim, the ground truth images and acquired foreground object are compared to find the number of erroneous pixels by counting the number of FP and FN. If a pixel marked as foreground in processed image, but marked as background in ground truth, then it is considered as FP. For opposite case, if a pixel marked as foreground by ground truth, but marked as background in processed image, then it is considered as FN. The sum of FP and FN denotes the error measure in terms of comparing the objective results. Specifically, the Total Errors, Total Errors without light switch (TE without LS) and Total Errors without Camouflage switch (TE without Camouflage) are demonstrated on the last columns of Table 2. The less error value indicates the best performance in terms of foreground segmentation.

The obtained statistical results are presented in Table 2. From the Table, one can derive that a superior performance is obtained by the proposed method, called CMA. In conjunction with visual results, the performance SG, MOG and KDE similar to each other. However, when the light switch video is excluded in case of performance evaluation, we can observe that the MOG and KDE generate better results than almost of all algorithms except CMA. These results are attributed to characteristic of probability based foreground and change detection property. Moreover, when the camouflage video is used and considered, the worst performance is produced by probabilistic based background subtraction methods. Also, comparing the subspace based methods including SL-PCA, SL-ICA and SL-INMF, one can note that the performance of SL-ICA is favourable against SL-PCA and SL-INMF. The performance of SL-PCA and SL-IRT are closed to each other, but difference bears in case of removing the light switch.

IV. CONCLUSIONS

In this study, the impact of CMA is evaluated for background modeling based foreground detection. The performance of the proposed method is compared with other well-known methods for dynamic backgrounds including Moved Objects, Time of Day, Light Switch Waving Trees, Camouflage, Bootstrap, Foreground Aperture. From the objective and subjective evaluation, it has observed that the proposed method exhibit eye pleasing results. The obtained experimental results present significant performance difference between PCA, ICA, INMF and probabilistic based methods (SG, MOG and KDE) in terms of accuracy and robustness to dynamic changes among the images for a given video. From the overall evaluation, one can emphasize that a smart post processing procedure is greatly needed to both accurately reveal the region of foreground object meanwhile perturbing the noisy pixels caused by uncontrolled changes, which are waving trees and illumination changes. As a future work, a comprehensive and universal background subtraction method is aimed to develop by using the concept of CMA.

REFERENCES