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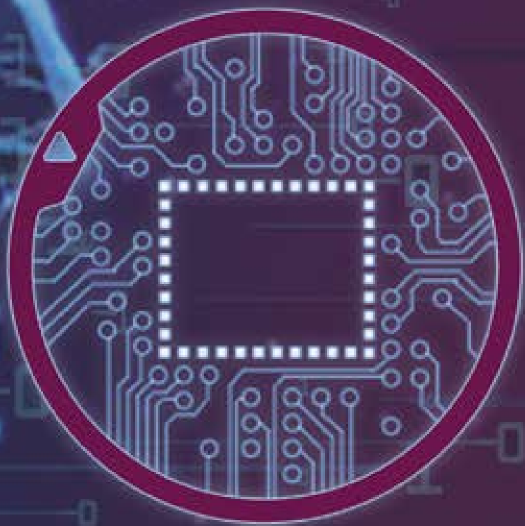

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Artificial Intelligence and Data Science
Research and Application Center

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Aim & Scope

The Journal of Artificial Intelligence and Data Science (JAIDA) is an international, scientific, peer-reviewed, and open-access e-journal. It is published twice a year and accepts only manuscripts written in English. The aim of JAIDA is to bring together interdisciplinary research in the fields of artificial intelligence and data science. Both fundamental and applied research are welcome. Besides regular papers, this journal also accepts research field review articles.

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ÖNSÖZ

Yapay Zeka ve Veri Bilimi alanındaki teknolojik ve bilimsel gelişmeler; Yapay Zekanın endüstri, sağlık, otomotiv, ekonomi, eğitim gibi bir çok farklı alanda uygulanmasına imkan sağlamıştır. Ülkemiz Ulusal Yapay Zeka Stratejisinde; yeni bir çağın eşiğine gelindiği, yapay zekayla üretim süreçleri, meslekler, gündelik yaşam ve kurumsal yapıların yeni bir dönüşüm sürecine girdiği vurgulanarak, Yapay Zekanın öneminden bahsedilmiştir.

Sayın Cumhurbaşkanımızın da belirttiği gibi ülkemiz adına insan odaklı yeni bir atılım yapmanın zamanının geldiğine inanıyoruz. Yapay zeka çağına geçiş noktasında Türkiye'nin lider ülkelerden biri olması motivasyonu ile üniversitemizde yapay zeka teknolojilerinin kullanıldığı projeler gerçekleştirmekte, kongreler ve bilimsel etkinlikler düzenlemekteyiz.

Günümüz dünyasına rengini veren dijital teknolojilerin odağındaki ana unsurun yapay zeka teknolojilerinin olduğu düşüncesi ile yola çıkarak hazırlamış olduğumuz Yapay Zekâ ve Veri Bilimi Dergisinin, Ülkemiz Ulusal Yapay Zeka Stratejisinde belirtilen "Dijital Türkiye" vizyonu ve "Milli Teknoloji Hamlesi" kalkınma hedefleri doğrultusunda katkı sağlayacağı inancındayız.

Dergimizin hazırlanmasında emeği geçen üniversitemiz Yapay Zekâ ve Veri Bilimi Uygulama ve Araştırma Merkez Müdürü, Baş Editör Prof. Dr. Ayşegül ALAYBEYOĞLU'na, Editör ve Danışma kurulu üyelerine, akademik çalışmaları ile sağladıkları destek için tüm yazarlara, hakem olarak görev alan değerli bilim insanlarına teşekkür eder, dergimizin yeni sayısının ülkemize hayırlı olmasını dilerim.

Prof. Dr. Saffet KÖSE, Rektör

Dergi Sahibi

PREFACE

Technological and scientific developments in Artificial Intelligence and Data Science enabled the application of Artificial Intelligence in many different fields such as industry, health, automotive, economy and education. In our country's National Artificial Intelligence Strategy; the importance of Artificial Intelligence was mentioned by emphasizing the transformation process of production processes, occupations, daily life and corporate structures with artificial intelligence.

As stated by our President, we believe that the time has come to make a new human-oriented breakthrough on behalf of our country. With the motivation of Turkey being one of the leading countries at the point of transition to the age of artificial intelligence, we realize projects in which artificial intelligence technologies are used, and organize congresses and scientific events at our university.

We have prepared the Journal of Artificial Intelligence and Data Science with the idea that the main element in the focus of digital technologies that color today's world is artificial intelligence technologies, and we believe that our journal will contribute to the development goals of the "Digital Turkey" vision and "National Technology Move" stated in the National Artificial Intelligence Strategy of our country.

I would like to thank Prof. Dr. Ayşegül ALAYBEYOĞLU, the Director of Artificial Intelligence and Data Science Application and Research Center of our university. I would also like to thank to Editor and Advisory Board members, to all authors for their supports with their academic studies and to reviewers for their contributions to the preparation of our journal. I wish the new issue of our journal to be beneficial for our country.

Prof. Dr. Saffet KÖSE, Rector

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BAŞ EDİTÖR'DEN

Değerli Araştırmacılar ve Dergi Okuyucuları;

İzmir Kâtip Çelebi Üniversitesi Yapay Zekâ ve Veri Bilimi Uygulama ve Araştırma Merkezi olarak Rektörümüz Prof. Dr. Saffet Köse sahipliğinde Yapay Zekâ ve Veri Bilimi Dergisinin ikinci cilt ikinci sayısını sizlerle buluşturmanın gururunu yaşamaktayız.

İzmir Kâtip Çelebi Üniversitesi Yapay Zekâ ve Veri Bilimi Uygulama ve Araştırma Merkezi olarak hedefimiz; Cumhurbaşkanlığı Dijital Dönüşüm Ofisi Başkanlığı ve Sanayi ve Teknoloji Bakanlığı tarafından hazırlanan "Ulusal Yapay Zekâ Stratejisi" hedefleri doğrultusunda dergi, kongre, eğitim, bilimsel etkinlikler ve proje faaliyetleri gerçekleştirerek ülkemizin yapay zekâ alanındaki gelişim sürecine katkı sağlamaktır.

Farklı üniversitelerden, bilimsel disiplinlerden ve alanlardan değerli araştırmacıların İngilizce dilinde hazırlamış oldukları 7 adet araştırma makalesi bu sayı kapsamında sunulmaktadır. Siz değerli araştırmacılarımızın destekleri ile kaliteyi daha da arttırarak en kısa sürede ulusal ve uluslararası indekslerde daha çok taranan bir dergi olmayı hedeflemekteyiz.

Dergimizin yayın hayatına başlaması ve tüm merkez faaliyetlerinde büyük desteklerini gördüğümüz başta Rektörümüz Prof. Dr. Saffet KÖSE olmak üzere; dergimize olan destekleri için tüm yazarlara, dergimizin yayına hazırlanmasında heyecanla çalışan ve çok büyük emek harcayan Baş Editör Yardımcılarına, Editör ve Danışma kurulu üyelerimize, hakem olarak görev alan tüm değerli bilim insanlarına en derin şükranlarımı sunarım.

Saygılarımla,

Prof. Dr. Ayşegül ALAYBEYOĞLU

Baş Editör

LETTER FROM THE EDİTOR-IN-CHIEF

Dear Researchers and Readers of the Journal,

As İzmir Katip Çelebi University Artificial Intelligence and Data Science Application and Research Center, we are proud to present you the volume 2 issue 2 of the Journal of Artificial Intelligence and Data Science (JAIDA), hosted by our Rector Prof. Dr. Saffet Köse.

As İzmir Katip Çelebi University Artificial Intelligence and Data Science Application and Research Center, our goal is; to contribute to the development process of our country in the field of artificial intelligence by carrying out journals, congresses, education, scientific events and project activities in line with the objectives of the "National Artificial Intelligence Strategy" prepared by the Digital Transformation Office of the Presidency of Türkiye and the Ministry of Industry and Technology.

7 research articles prepared by valuable researchers from different universities, scientific disciplines and fields are presented within the scope of this issue. With the support of esteemed researchers, we aim to increase the quality even more and become a journal that is scanned in national and international indexes more as soon as possible.

I would like to express my deepest gratitude to Our Rector, Prof. Dr. Saffet KÖSE, who supported the publication of our journal and the research center's activities; to all the authors for their support to our journal; to our Associate Editors, who worked enthusiastically and put great efforts into the preparation of our journal; to our Editorial and Advisory Board members, and all esteemed scientists who served as reviewer.

Best Regards,

Prof. Dr. Ayşegül ALAYBEYOĞLU

Editor-in-Chief

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Research Article

A K-Shot Learning Algorithm for Transportation Mode Identification

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Abstract
Transportation mode identification (TMI) is to detect information about the movement behavior of individuals (i.e., car, bus, train) by using sensors embedded in a wearable device such as a smartphone and wristband. Most TMI methods can only recognize the activities that were previously seen in the training data. However, they cannot be able to detect an unseen activity without having any corresponding training sample. In this study, we propose a *k-shot learning* algorithm. When *k* is set to zero, named *zero-shot learning*, it can recognize a previously unseen new transportation mode (i.e., bus) even when there are no training samples of that mode in the dataset. The proposed method extends the recognition ability by incorporating the semantic information between seen and unseen classes. The experiments were carried out on a real-world dataset which was collected from 13 different participants via 15 sensors, containing 5 different modes which are train, car, standing still, walking, and bus. The results showed that the accuracy rates from 89.46% to 93.94% were achieved by the proposed method with different values of parameter *k*. The results also showed that our method outperformed the state-of-the-art methods on the same dataset in terms of classification accuracy.
Keywords: Classification; k-shot learning; machine learning; transportation; sensors.

1. Introduction

Transportation mode identification (TMI) is a special type of activity recognition task in which a dataset collected from wearable devices carried by persons is utilized to intelligently detect what traveling mode the users have used (i.e., car, bus, train). TMI is significant for many reasons that concern gathering data for developing transportation-related applications, allowing for targeted advertisements, planning urban transportation, providing better recommendations for mental and physical health improvement, and encouraging users to green transportation habits to protect the environment.

Most TMI studies built a classifier that can recognize only seen classes present in the training set. They have demonstrated promising results by classifying activities whose samples have already been seen during training. However, in real-life practice, the system should cover a growing number of human activities, some of whose samples will not be present in the training dataset. Covering all possible activities in advance is an expensive and complex task. Therefore, we need to develop a method that can extend the machine learning model to recognize unseen activities without prior knowledge concerning sensor data about previously unseen activities.

In summary, this study provides the following contributions. (i) It proposes a *k-shot learning* algorithm that improves the ability of a classifier such that the unseen class labels, which are not present in the training set, can be detected during testing. (ii) In addition to seen transportation modes (car, train, still, walking), our method achieved high performance in recognizing a previously unseen new transportation mode (bus). (iii) The experiments indicated that the proposed method outperformed the state-of-the-art methods in terms of classification accuracy on the same dataset.

The remainder of the paper is organized as follows. Section 2 reviews some related works in the field of TMI. Section 3 introduces our proposed method. Section 4 describes the dataset used in this study, and then, it evaluates our method on it in terms of prediction accuracy. It also presents the comparison of our method with state-of-the-art methods. Finally, Section 5 concludes the study with discussions.

2. Related Work

The earlier research in transportation mode identification (TMI) has used machine learning (ML), which is a powerful tool to predict or classify a given instance according to historical data [1]. TMI is currently approached using a dataset from different sensors embedded in wearable devices such as smartphones, smart watches, or wristbands [2]. These sensors measure position and motion in three-dimensional space and various environmental conditions. The most common sensors that have been used for TMI are an accelerometer, gyroscope, magnetometer, and barometric pressure [3]. There are also video-based solutions that extract features from continuous images of a video to detect transportation-related activities. Nevertheless, they have limitations such as high processing costs, personal privacy, insufficient light in environments, and working in a limited area where

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cameras are placed. For this reason, in this study, we focused on wearable sensor-based transportation mode identification.

In recent years, ML methods have been applied to different datasets, which categorize different activities by using different types of sensors, for transportation mode detection purposes. There are four commonly-used datasets. The first one is the GeoLife dataset [4] which was collected from 182 users over more than three years and contains GPS data. The second one is the Sussex-Huawei Locomotion Transportation (SHL) dataset [5] which was collected from three users for 7 months using 15 sensors. The third one is the HTC dataset [6] which contains the records gathered from three sensors (accelerometer, gyroscope, and magnetometer) in a period of 8311 hours. Lastly, the US-TMD (Unconstrained Sensors Transportation Mode Dataset) [7] was collected by 13 users and consists of 31 hours of sensor data, which was also used in this study.

The datasets are usually captured using mobile phones as raw data, and then, they are pre-processed by using a windowing method to extract features such as max, min, mean, and standard deviation, before creating models on them. When building models, different machine learning methods have been used such as random forest [2], support vector machines [8], neural networks [9], extreme gradient boosting [10], and decision trees [7]. Deep learning methods have also been tested for TMI, including convolutional neural networks (CNN) [3] and long short-term memory (LSTM) [11].

Supervised learning methods have been usually applied to the datasets by different researchers, each of which produced different accuracies and has different advantages and disadvantages. For example, the initial work on the US-TMD dataset [7] was conducted by its creators by generating three different training datasets considering energy consumption. The first dataset has only 3 sensor information, the second one includes 8 sensors while the third set contains 9 sensor information. They achieved the maximum accuracy (93%) on the third dataset by using the random forest algorithm.

In the literature; k-shot learning, zero-shot learning, one-shot learning, and few-shot learning have been used in many different areas such as health [12], education [13], manufacturing [14], agriculture [15], and finance [16]. There are also some papers that used these methods in the field of human activity recognition. Zhang et al. [17] proposed a graph-based few-shot learning model for the channel state information data using a feature extraction layer, including the convolutional block attention module. Kasnesis et al. [18] presented a one-shot learning algorithm relying on modality-wise relational reasoning. Zheng et al. [19] proposed a graph prototypical model using a few-shot learning algorithm for sensor-based human activity recognition.

Although some works used the k-shot algorithm in the literature, only a limited number of papers have focused on this method for particularly transportation mode identification. Hamidi and Osmani [20] tested few-shot recognition performances on the SHL dataset. Mishra et al. [21] combined the concepts of deep learning and zero-shot learning for detecting unseen locomotion modes on the SHL dataset.

3. Material and Methods

3.1. Background information

The most widely adopted types of learning are supervised learning, unsupervised learning, and semi-supervised learning (SSL). In addition to these, *k-shot learning* is to learn to classify an object when only a limited number of training instances (only *k* samples) for a class are available as supervision. In particular, *zero-shot learning* (ZSL) is referred to as learning, where the classes covered by testing and training samples are disjoint. In the testing phase, it uses semantic information to classify an object that belongs to a previously unseen class. Figure 1 shows the differences among different types of learning. In supervised learning, all instances have a class label and all class labels are seen by the model during the training phase. On the contrary, in zero-shot learning, there is at least one unseen class whose samples are not present in the training dataset. In unsupervised learning, training samples are not annotated as a whole, for this reason, the samples are clustered according to their similarities. In semi-supervised learning, only a part of the training data samples from all classes have labels. The difference between ZSL and SSL is that training instances are available for all classes in SSL whereas no training instances are provided for a test category in ZSL. In k-shot learning, the model is trained with only a few instances (*k* instances) from one class label. In case the training set includes only one instance from a class, it is called one-shot learning. Similarly, if two instances are available for the class, it is called 2-shot learning. When *k* is set to 3, it is referred to as 3-shot learning, and so on.

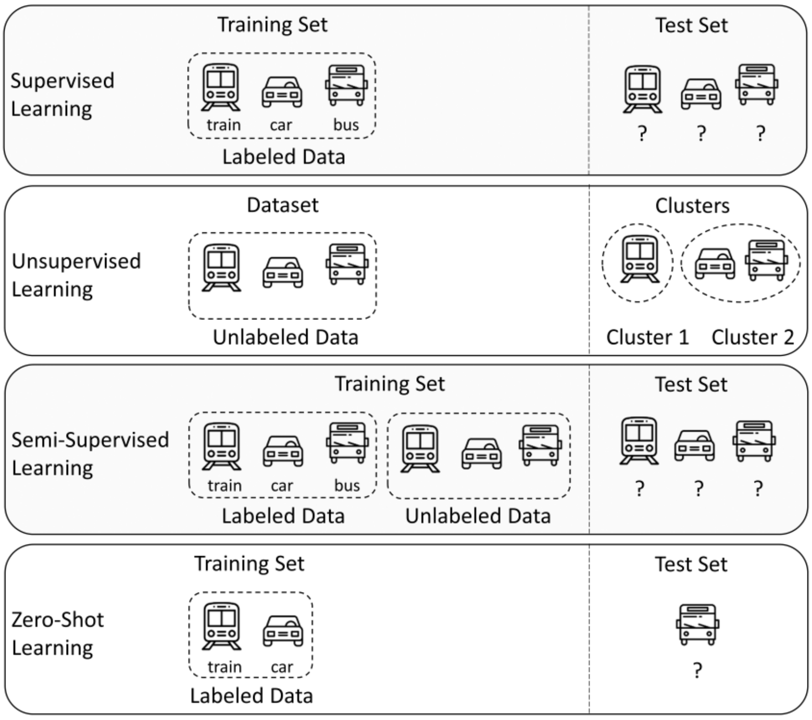


Figure 1. *The differences among different types of learning.*

In this study, we built a classifier that could recognize previously unseen or few-seen classes in the training set by incorporating the concept of k-shot learning. For example, the training set only includes instances that belong to the "car" and "train" classes. When *k* is set to zero, the model can recognize a previously unseen new transportation mode (i.e., bus) even when there are no training samples of that mode in the dataset.

3.2. Proposed method

This paper proposes an approach that involves k-shot learning for recognizing unseen class labels (transportation modes). Figure 2 shows a sketch of the classification of transportation modes with k-shot learning. (i) *Data collection*: We used the US-TMD dataset [7] collected from 13 different participants via 15 sensors, containing 5 different modes which are *train*, *car*, standing *still*, *walking*, and *bus*. (ii) *Data preprocessing*: Missing values were imputed with the average value of each attribute. Furthermore, some sensor values (light, gravity, magnetic field, uncalibrated magnetic field, pressure, and proximity) were excluded since they are not representative of the transportation mode. (iii) *Feature extraction*: In machine learning, directly using raw signal data is usually not practical because it doesn't carry sufficient information to distinguish transportation modes. Therefore, in this study, features were extracted to obtain meaningful information from the raw data. After dividing the dataset into 5-second windows, we extracted four features (mean, standard deviation, minimum, and maximum) for each sensor from the windows. Here, each window corresponds to a single transportation mode such as driving a car activity. Consequently, we have obtained 36 features (4 features * 9 sensors). (iv) *Training*: We adopted the Random Forest algorithm with the concept of k-shot learning and applied it to the cleaned data. (v) *Testing*: We tested our model with different values of parameter *k* (zero-shot, 1-shot, 100-shot, etc.) by using the classifier and semantic information together and evaluated its performance for an unseen or few-seen class label. Finally, classification output can provide context information useful to recommend appropriate services based on the needs of users.

A classical predictive model can only detect seen class labels that are given in training samples. On the other hand, such a model cannot recognize an unseen class label that appears for the first time during the test phase. Zero-shot learning is a useful method that extends the ability of a conventional model for detecting unseen classes. In this type of learning, an unseen class can be recognized by using semantic information between seen and unseen classes.

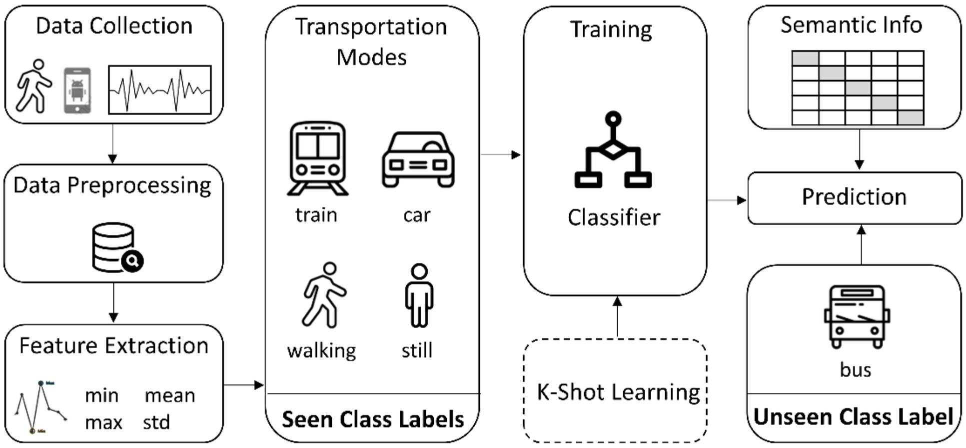


Figure 2. *The general overview of the proposed approach.*

Table 1 presents the semantic matrix that involves common characteristics of transportation modes. We considered all the relevant characteristics given in [21], including speed, wheel, pathway, fuel, power, and capacity. For example, the same pathway characteristic is observed in both "bus" and "car" transportation modes. Min-max normalization technique was applied to the matrix to be able to prevent an attribute from being more dominant than others. For example, the "power" attribute is the most dominant feature with high values that affects the result without applying normalization. The min-max normalization is given in Eq. (1).

$$F_{a,b_{normalized}} = \frac{f_{a,b} - min\,(f_{a,1}, f_{a,2}, \dots, f_{a,r})}{max\,(f_{a,1}, f_{a,2}, \dots, f_{a,r}) - min\,(f_{a,1}, f_{a,2}, \dots, f_{a,r})} \quad for\ a = 1,2,\dots,r \ \wedge \ b = 1,2,\dots,q \tag{1}$$

where F is the set of all characteristic values per activity such that $F = \left[\left(f_{1,1}, f_{1,2}, \dots, f_{1,q}\right), \dots, \left(f_{r,1}, f_{r,2}, \dots, f_{r,q}\right)\right]$, r is the number of activities, and q is the count of characteristic types.

Table 1. *Semantic matrix [21] and its normalized counterpart.*

	Speed	Wheel	Pathway	Fuel	Power	Capacity	Speed	Wheel	Pathway	Fuel	Power	Capacity
Bus	100	6	0	1	24000	45	0.833333	0.107143	0	0.333333	0.034286	0.030738
Train	110	56	1	2	700000	1464	0.916667	1	1	0.666667	1	1
Car	120	4	0	0	17000	4	1	0.071429	0	0	0.024286	0.002732
Still	0	0	0	3	0	0	0	0	0	1	0	0
Walking	5	0	0	3	37	0	0.041667	0	0	1	0.000052	0

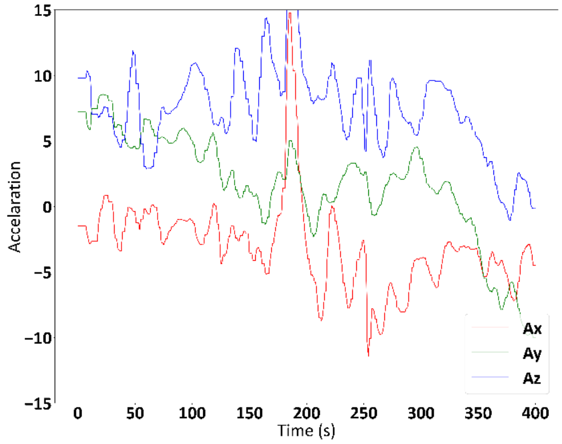
Table 2 shows the similarities between each activity pairs in the set. In the creation of the matrix, cosine similarity was used to have a clear understanding of similarities between seen and unseen classes. As can be seen from the table, it is clear that the bus transportation mode is more similar to train and car, rather than standing still and walking. The formula of cosine similarity is given in Eq. (2), which is an operation that always results in an interval [0,1].

$$\cos(\mathbf{t}, \mathbf{e}) = \frac{\mathbf{te}}{\|\mathbf{t}\|\|\mathbf{e}\|} = \frac{\sum_{i=1}^{q} \mathbf{t}_i \mathbf{e}_i}{\sqrt{\sum_{i=1}^{q} (\mathbf{t}_i)^2} \sqrt{\sum_{i=1}^{q} (\mathbf{e}_i)^2}} \tag{2}$$

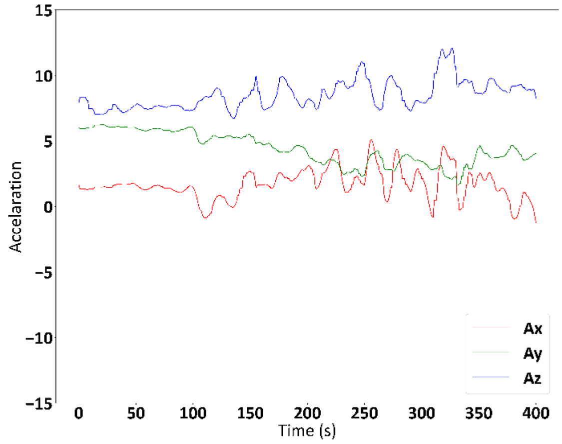
Table 2. *Similarity matrix of transportation modes.*

	Bus	Train	Car	Still	Walking
Bus	1	0.5566	0.9275	0.3682	0.4063
Train	0.5566	1	0.4403	0.2900	0.3063
Car	0.9275	0.4403	1	0.0000	0.0415
Still	0.3682	0.2900	0.0000	1	0.9991
Walking	0.4063	0.3063	0.0415	0.9991	1

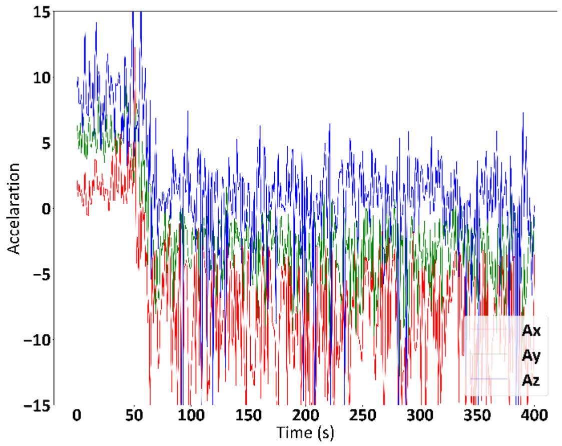
Figure 3 shows the graphical plots of the raw sensor data that was acquired from the 3-axis accelerometers of the phones used in the data-collecting phase. These figures are useful to have a basic understanding of the transportation modes. Letter 'A' in the plots represents the accelerator sensor and X, Y, and Z letters represent the direction of the accelerator. Each activity was plotted with a 400-seconds part of the raw data presented within the range of [-15, 15] signal amplitude. As can be seen in Figure 3, the walking activity has the biggest and most prominent frequency and amplitude range value when comparing it with the other activities. On the contrary, the train and standing still activities have small fluctuations and lower signal amplitude ranges than others. It can be observed that the similarity between bus (unseen class) and car (seen class) is higher than the similarity between bus and other seen classes.



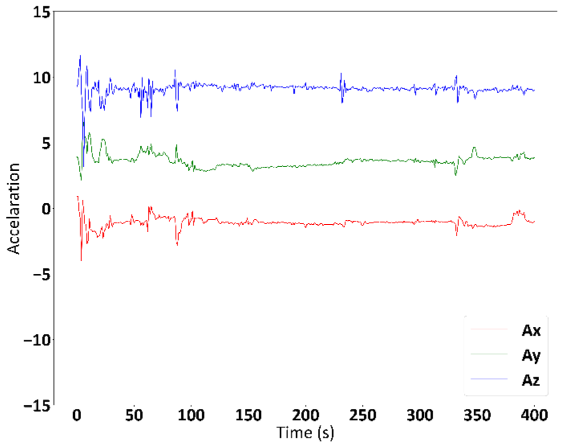
(a) *Bus*



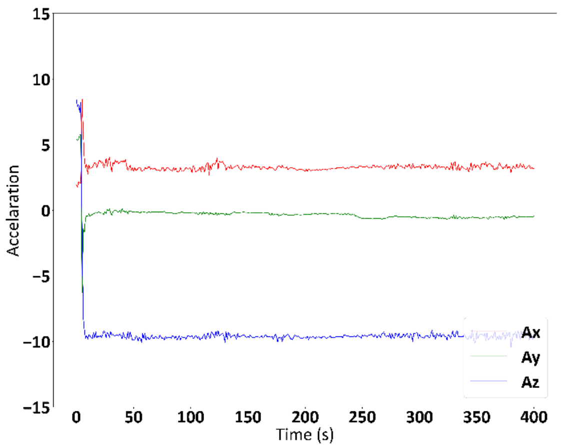
(b) *Car*



(c) *Walking*



(d) *Still*



(e) *Train*

Figure 3. *Sample accelerometer sensor data in three axes (x, y, z) over time for each transportation mode.*

The proposed transportation mode identification system has important benefits and is particularly significant for developing many transportation applications.

- Information about the transportation modes of residents is useful for improving urban transportation planning. For instance, which types of vehicles are mainly preferred? What are the common transportation modes (i.e., walking, biking) they use while getting home or business? The answers to these questions can help governments to better understand the requirements of citizens and develop better services.
- Automatic gathering of transportation demand information via smartphones is easier than supplementing the conventional information acquisition practice based on questionnaires and telephone interviews, which is time-consuming and expensive.
- It is possible to facilitate customized and targeted services and advertisements based on the transportation modes of the users. For instance, if a person travels in a bus, books can be advertised; on the other hand, if she/he drives a car, some vehicle services advertisements can be shown.
- The information on transportation modes can improve the performance of positioning and localized systems. Location-based smart services and advertising are potential targets of TMI.
- Several movement disorders and lifestyle diseases are associated with inactivity; therefore, recognizing activities can be used to give information to prevent diseases. For example, it could be used to offer walking or biking activities to smartphone users, instead of taking a car or bus for a short journey. Furthermore, it can provide useful feedback to the doctor since walking or biking activities are associated with health.
- The CO_2 footprint of individuals can be better monitored with the information. To protect the environment, the data can help users encourage green transportation habits through recommendation technologies.

3.3. Formal description

Let D be a labeled training set with n instances such that $D = \{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\}$ where x_i is the d-dimensional input vector and $y_i \in Y_s$ is the corresponding class label (transportation mode). Y_s is the set of *seen* classes whereas Y_u is another set that contains classes that are *unseen* when training a model such that $Y = Y_s \cup Y_u$ $=\{\{c_1, c_2, \ldots, c_s\},\{c_{s+1}, c_{s+2}, \ldots, c_{s+u}\}\}$. The important point about zero-shot learning is that $Y_s \cap Y_u = \emptyset$ which means that the seen (training) and unseen (test) classes are disjoint. When building a classifier in traditional ML, it is usual to use Y which is the set consisting of all the target classes. The main aim is to find a mapping function $f : x \rightarrow y$ that can recognize the class label of a given query instance. K-shot learning extends the recognition ability by incorporating the semantic information attributes (denoted by A) between seen and unseen classes such that $f : (x, A) \rightarrow y$. It builds a model M that can classify all the activities in the set Y by only considering the set Y_s in the training phase, but without seeing any member of Y_u.

Algorithm 1 presents the pseudo-code of the proposed k-shot learning (KSL) algorithm. KSL has the ability to predict an unseen class (c), but without having any example of that class (called zero-shot) or only having a few examples (k-shot) in the training set. Recognizing a previously unseen class often involves an analysis of the similarity between seen and unseen classes. First, a classifier model (M) is built by using a machine learning algorithm. Given a new test query x_i, the maximum likelihood is decoded using model M. After that, the prediction is made by mapping to the nearest neighbor (NN) of that unseen class. In other words, the output o is produced according to the nearest classes corresponding to the unseen class c in semantic matrix attributes A.

Algorithm 1. K-Shot Learning

Inputs: D: Training set
T: Testing set
A: Semantic attributes
c: unseen class label
k: the number of instances from unseen class
Output: O: Predicted class labels

```
1:  M = Train(D);
2:  NN = NearestNeighbors(A, c)
3:  for i = 0 to |T| do
4:      probabilities[] = M.predict(x_i)
5:      for j = 0 to |Y| do
6:          if (probabilities[j] > max) then
```

```
            maxIndex = j
            max = probabilities[j]
        end if
    end for
    if (k != 0 and classes[maxIndex] = c) then
        o = Assign class label c to x_i
    else if (k = 0 and classes[maxIndex] in NN) then
        o = Assign class label c to x_i
    else
        o = Assign predicted class label to x_i
    end if
    O = O ∪ o
end for
```

4. Experimental Studies

The effectiveness of the proposed k-shot learning method was demonstrated on the TMD dataset. The method was implemented in C# by using the Weka machine learning library [22]. The k-fold cross-validation was performed to evaluate the predictive performance of the machine learning model. The accuracy metric was used to calculate the proportion of correct predictions of the model to total prediction, like the study [23].

4.1. Dataset description

The US-TMD dataset [7] was used in this study, which is publicly available and collected via an Android application. It was released by researchers at the University of Bologna. This dataset is one of the popular and important benchmark datasets in the field of transportation mode detection. It has been used in previous studies [7-9, 20, 24], so it can be utilized for making comparisons with them. The raw data was gathered by taking help of 33 users with different gender, age, and occupations, which resulted in a total of 31 hours of data. There are 9 sensors used in every device, including accelerometer, orientation, speed, sound, gyroscope, linear acceleration, gyroscope uncalibrated, game rotation vector, and rotation vector. Each sensor measures different physical quantities and provides corresponding signal readings about the transportation modes of individuals. With the advances in electronic devices and technology, sensors are becoming smaller in size, cheaper, and powerful. This makes it usual and easy to use in our daily life and useful tool for collecting data and using it in scientific studies. Currently, most smartphones contain sensors that allow capturing of significant context information. Therefore, in this study, smartphones were used to collect data while users were performing five activities, including walking, standing, and traveling with bus, train, and car.

The raw data were saved locally with a maximum frequency of 20 Hz in the following format: <timestamp, sensor, sensorOutput>. Here, the progress is followed by a user using the Graphical User Interface of the application: (i) Entering her/his information e.g., name, the action that is being done by the user. (ii) Touching the start button. (iii) Touching the stop button when the action is completed. The raw data consists of 226 text files, each one includes the same number of activities. The percentages of each activity in the dataset are as follows: walking 26%, standing still 24%, driving a car 25%, being on a bus 5%, and being on a train 20%.

4.2. Experimental results

Figure 4 shows the performance of the proposed method on different parameter *k* values in terms of accuracy. *Accuracy* is the metric used to measure the ability of the classifier to make an accurate prediction. There are four well-known building blocks of accuracy metrics which are as follows, (i) *True Positive (TP):* Correctly classified positive observations. (ii) *True Negative (TN):* Correctly predicted negative observations. (iii) *False Positive (FP):* The incorrect prediction of the positive class. (iv) *False Negative (FN):* The incorrect prediction of the negative class. Based on the accuracy rates, it is possible to say that all the models have good classification ability. The performance of the method is particularly high even though the number of shots is very small (i.e., 1-shot). Hence, it can be concluded that few seen classes can be successfully recognized by the method since the semantic matrix provides meaningful information about seen classes, which is later helpful for detecting an unseen class. The method improves performance as the number of shots increases.

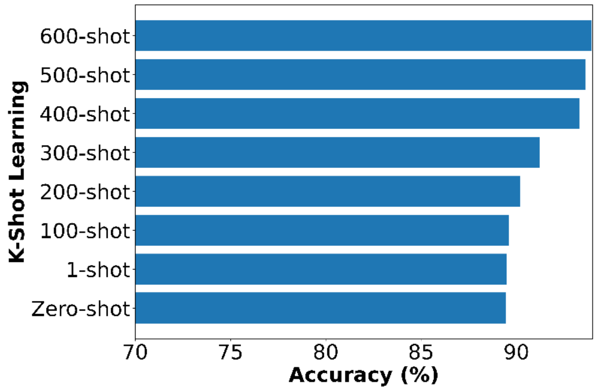


Figure 4. *The prediction performance of the proposed k-shot learning algorithm.*

Figure 5 shows the top-10 values obtained by the random forest method to determine the importance of each feature. The method calculates how each feature is correlated with the target class attribute through a pair-wise comparison. In other words, we identified the most critical features that affect transportation mode detection. As seen in the figure, the top-10 feature ranks range between approximately 0.035 and 0.075. A large value means that the corresponding feature is more significant. According to the results, the standard deviation of accelerometer sensor values affects prediction the most. It is followed by the mean value of the linear acceleration. Gyroscope-related features are also placed in the top-10. As can be observed from Figure 5, speed is also another important feature that is needed to understand the underlying behavior of a transportation mode. It is clear that different transportation modes have different speed patterns. For example, the mean of speed is a distinguishing feature in walking activity when comparing it with the others. While the speed is very low in walking and standing activities, it has higher values in car, train, and bus activities. On the other hand, sound sensor values are less-correlated with the output values than other sensors, but it is still in the top-10 feature ranks. For example, some old trains may have higher loud tones than other transportation modes.

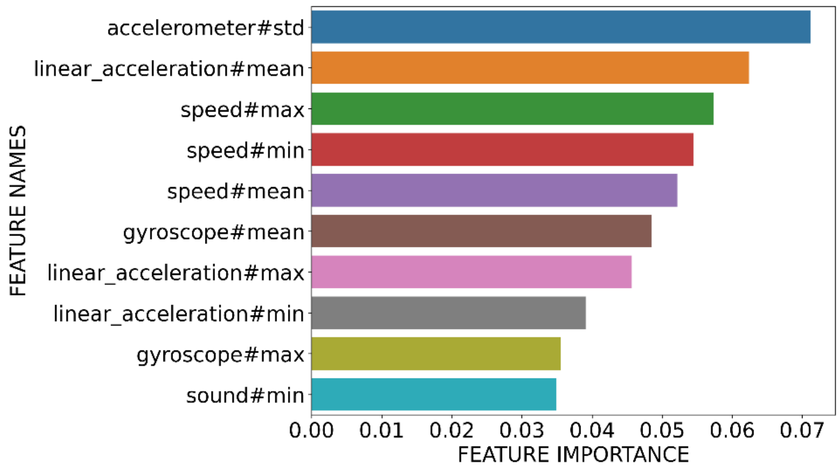


Figure 5. *Top-10 important features.*

4.3. Comparison with the state-of-the-art methods

To show the superiority of the proposed approach, it was compared with the state-of-the-art methods [7-9, 20, 24]. The results were directly taken from the original publications since the authors used the same dataset [7] as our study. Table 3 presents the existing studies with their methods and accuracy rates. It is possible to see from the table that our k-shot learning method achieved higher accuracy (93.94%) than others on the same dataset. When the parameter *k* was set to 600 the proposed method outperformed the other methods with an 8.85% improvement on average. Therefore, our proposed method could be effectively used to detect the transportation modes of individuals.

Table 3. *Comparison of our method against the previous methods on the same dataset.*

Reference	Year	Method	Accuracy (%).
Hamidi and Osmani [20]	2021	Metamodeling without privileged information (wo-Prvlg)	71.32
		Metamodeling with human expertise (w-HExp)	80.28
		Metamodeling with privileged information (w-Prvlg)	83.64
Roy et al. [8]	2021	Support vector machine	88.00
		K-nearest neighbors	91.60
		Decision tree	86.00
		Bagging	92.00
		Random forest	93.20
Hamidi and Osmani [24]	2021	Random search	74.14
		Grid search	72.21
		Naive evolution	79.71
		Anneal search	81.13
		Hyperband (HB)	80.80
		Bayesian optimization hyperband (BOHB)	79.17
		Tree-structured parzen estimator (TPE)	84.39
		Gaussian process tuner (GP Tun)	83.64
Carpineti et al. [7]	2018	Decision tree	86.00
		Random forest	93.00
		Support vector machine	90.00
		Neural network	91.00
Johansson and Ewerbring [9]	2018	Decision tree	86.00
		Support vector machine	91.00
		Random forest	93.00
		Neural network	91.00
		Average	**85.09**
Proposed method		**K-shot learning (KSL)**	**93.94**

5. Conclusion and Future Work

In recent years, with the increase in urbanization and the widespread use of portable devices such as tablets, phones, and smartwatches, applications that are aware of the user's transportation activity have gained importance. In this paper, we present a k-shot learning algorithm that can recognize previously unseen or few-seen transportation modes. It can be useful in case of a lack of data about some class labels. Our approach leveraged the semantic information among the transportation modes to learn how close they are to each other. On a real-world dataset, our algorithm reached accuracy rates from 89.46% to 93.94% with different parameter values. In addition to seen transportation modes (car, train, still, walking), the proposed method achieved high performance in recognizing a previously unseen new transportation mode (bus). On average, it achieved higher accuracy (93.94%) than the previous methods (85.09%) on the same dataset. Hence, it outperformed the state-of-the-art methods with an 8.85% improvement on average. In conclusion, our proposal provides a robust algorithm with high accuracy on unseen or few-seen data and can be applied across scientific research which has a limited amount of data for some classes.

In the future, the proposed method can be used in applications for different purposes such as allowing for targeted advertisements, planning urban transportation, providing health recommendations, and encouraging users to green transportation habits to protect the environment. It can play an important role in improving services such as smart parking, vehicle traffic monitoring, and personal safety. This paper also brings us two new questions, one is whether can people be identified by extracting their transportation mode practices, and the second is whether can group-based transportation activities be identified. For future work, the interpretation of collective transportation activities through portable smart devices can be studied to improve related services.

Declaration of Interest

The authors declare that there is no conflict of interest.

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Research Article

Accuracy Comparison of CNN Networks on GTSRB Dataset

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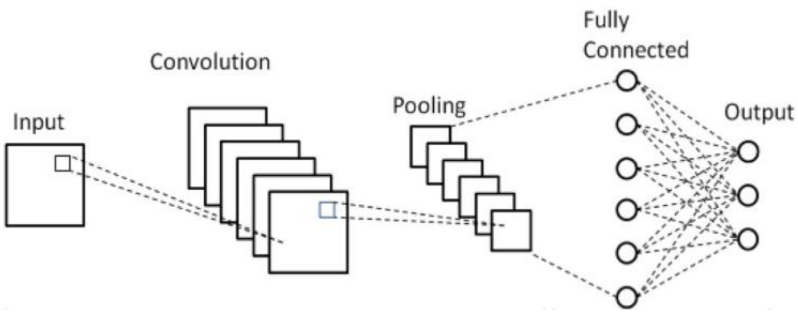
Abstract
In this era, interpreting and processing the data of traffic signs has crucial importance for improving autonomous car technology. In this respect, the relationship between the recognition of traffic signs and industrial applications is highly relevant. Although real-world systems have reached that related market and several academic studies on this topic have been published, regular objective comparisons of different algorithmic approaches are missing due to the lack of freely available benchmark datasets. From this point of view, we compare the AlexNET, DarkNET-53, and EfficientNET-b0 convolutional neural network (CNN) algorithms according to validation performance on the German Traffic Signs Recognition Benchmark (GTSRB) dataset. Considering the equal training and test conditions 70% of data as training, 15% of data as training validation, and 15% of data were chosen as test data. Experimental results show us that EfficientNET-b0 architecture has 98.64%, AlexNET architecture has 97.45% and DarkNet-53 architecture has 94.69% accuracy performance.

Keywords: AlexNET; CNN; DarkNET-53; EfficientNET-b0; GTSRB; Traffic Sign Classification.

1. Introduction

The Convolutional Neural Network (CNN) is a kind of deep learning way that heap various convolutional layers in sequence. Nowadays, CNN has become a revolutionary technique in the field of artificial intelligence for classifying objects. Owing to this point of view, the classification of traffic signs has crucial importance in both constructing healthy traffic for humans and avoiding accidents. Although the classification of objects is easy-task for humans in common-used items used in daily routine, the classification of traffic signs is not so under complex scenarios [1]. The generalized basic block diagram of the CNN is given in figure 1 below.

Figure 1. *Generalized block diagram of CNN [2].*



The main causes of these signs being misunderstood are the quality of sign material, blurry images, background color intersection, and weak light or weather conditions. An ideal traffic sign recognition system that has vital importance for automated drive systems comprises detection and classification implementations. The real-time performance of classification has a crucial effect on decisions instantly. The German Traffic Signs Recognition Benchmark (GTSRB) [3] dataset is created for challenging this performance comparison. Dataset has 43 classes with over 50000 real-taken pictures. The random example representatives of 43 classes in GTSRB dataset is given in figure 2 below.

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Figure 2. *Random example representatives of 43 classes in GTSRB Dataset* [4].

Based on the serial development of computer vision systems, derived new methods enable accurately classifying complex objects. Classification of traffic signs seems basic because of their shapes or colors but it has a complex challenge concerning environmental items [5]. The main problems in that matter like bad conditions, low image quality, image blurring, and the same image color between the environment and traffic signs, etc.

Nowadays, machine learning [6] contains a hot topic called deep learning which is used for classification [7], [8], detection [9], [10], and recognition [11], [12] with achieved beyond the success of traditional methods like support vector machine (SVM) [13] or extreme learning machine (ELM) [14], [15]. When the traffic sign data has some trouble qualifications like shaded or occluded image, the accuracy rate may be decreased. Especially, the big training data enhance the generalizability of deep learning while the large model structure and its nonlinearity. According to the official results of the publication of the GTSRB dataset, various top five methods and research results are shown in Table 1.

Table 1. *Top five methods and performances of GTSRB dataset.*

No	Method	Performance
1	CNN with 3 Spatial Transformers [16]	99.71 %
2	Committee of CNNs [17]	99.46 %
3	Color-blob-based COSFIRE filters for object recognition [18]	98.97 %
4	Human Performance [4]	98.84 %
5	Multi-Scale CNNs [19]	98.31 %

This article compares three of CNN algorithm architectures accuracy performances: AlexNET, DarkNET-53, and EfficientNET-b0, respectively. Details of the respective algorithms are described in Chapter II, and the details of simulation results and discussions are presented in Chapter III. Chapter IV interprets the performances and future-works of the architectures and draws conclusions.

2. Materials and Method

2.1 AlexNET Architecture

The Large-Scale Visual Recognition Challenge (LSVRC) is a competition in which research groups participate to evaluate learning algorithms on a large-label image dataset (ImageNet). The competition aimed to achieve higher accuracy in various visual recognition tasks. AlexNET is a type of convolutional neural network architecture developed by Alex Krizhevsky which won the LSVRC competition in 2012 [20]. A tabular representation of the architecture is shown in Table 2.

Table 2. *AlexNET architecture* [20]

Layer	Filter Size	Size	Activation Function
Input	-	227x227x3	-
Convolution 1	11x11	55x55x96	ReLu
Max Pooling 1	3x3	27x27x96	-
Convolution 2	5x5	27x27x256	ReLu
Max Pooling 2	3x3	13x13x256	-
Convolution 3	3x3	13x13x384	ReLu
Convolution 4	3x3	13x13x384	ReLu
Convolution 5	3x3	13x13x256	ReLu
Max Pooling 3	3x3	6x6x256	-
Dropout 1	-	6x6x256	-
Fully Connected 1	-	4096	ReLu
Dropout 2	-	4096	-
Fully Connected 2	-	4096	ReLu
Fully Connected 3	-	1000	Softmax

2.2 DarkNET-53 Architecture

Image classification is a kind of application area of convolutional neural networks. YOLO (You Look Only Once) is an efficient real-time object recognition algorithm first described [21].

Darknet-53 is a convolutional feature extraction network mainly consisting of a series of 1x1 and 3x3 convolutional layers, with a total of 53 layers including the last fully connected layer but excluding the residual layer. Each convolutional layer is followed by a batch normalization (BN) layer [22] and a LeakyReLu [23] layer. A tabular representation of the architecture is shown in table 3.

Table 3. *DarkNET-53 architecture* [24].

Layer	Filter Size	Repeat	Output Size
Input	-	-	416x416
Convolution	3x3	1	416x416
Convolution	3x3	1	208x208
Convolution	1x1	1	208x208
Convolution	3x3		208x208
Residual			208x208
Convolution	3x3	1	104x104
Convolution	1x1	2	104x104
Convolution	3x3		104x104
Residual			104x104
Convolution	3x3	1	52x52
Convolution	1x1	8	52x52
Convolution	3x3		52x52
Residual			52x52
Convolution	3x3	1	26x26
Convolution	1x1	8	26x26
Convolution	3x3		26x26
Residual			26x26
Convolution	3x3	1	26x26
Convolution	1x1	4	13x13
Convolution	3x3		13x13
Residual			13x13

2.3 EfficientNET-b0 Architecture

EfficientNET can be defined as both convolutional neural network architecture and a scaling method that uniformly scaled the dimensions of network depth width and resolution, respectively in a compound coefficient called fi constant. The intuition justifies the compound scaling method that if the input image is bigger, the network needs more layers to increase the receptive field and more channels to capture more fine-grained patterns on the bigger image [25].

Contrary to other classical CNN architectures, EfficientNET uses an inverted residual block called MBConv which was initially proposed for the architecture of MobileNETV2 [26] for improving efficiency causes. EfficientNET has various versions from b0 to b7 inside itself, in this paper the b0 version is selected. The total amount of parameters in EfficientNet-b0 architecture is 5.3 million. The tabular representation of the EfficientNET-b0 baseline network is given in Table 4.

Table 4. *EfficientNET-b0 architecture* [25].

Layer	Filter Size	Resolution
Input	-	224x224
MBConvolution	3x3	112x112
MBConvolution	3x3	112x112
MBConvolution	5x5	56x56
MBConvolution	3x3	28x28
MBConvolution	5x5	14x14
MBConvolution	5x5	14x14
MBConvolution	3x3	7x7
Convolution	1x1	7x7
Pooling & Fully Connected	-	7x7

3. Results and Discussion

In our work, to provide an efficient training, 70% of the GTRSB data set were utilized for training, whereas the remaining 30% was employed for training validation and test data as 15%-15% respectively. In that regard, we observe that classification provided by the EfficientNet-b0 of CNN algorithms allows us to classify the traffic signs dataset better. To this end, according to simulation results that were obtained from MATLAB, all the algorithms performed quite well, i.e., with an accuracy of 94.69%, 97.45% and 98.64% for DarkNet-53, AlexNET and EfficientNET-b0, respectively. As might be shown from the obtained results, the EfficientNET-b0 algorithm takes the best result with 98.64 % accuracy (performance) value on GTSRB dataset. Obviously, the performance of EfficientNET-b0 can be considered as one of the outperformers according to the results summarized in Table 1.

The performance comparison of the related CNN algorithms is tabularized in Table 5.

Table 5. *Comparison results of related CNN algorithms.*

Layer	Performance (%)
EfficientNET-b0	98.64 %
AlexNET	97.45 %
DarkNET-53	94.69 %

4. Conclusion

In this paper, trained AlexNET, DarkNET-53, and EfficientNET-b0 models for classifying the German Traffic Signs Recognition Benchmark dataset were successfully implemented in the simulation base. Here, the classification methods based on related CNN architectures were implemented on MATLAB and analyzed with evaluation metrics. The simulation outcomes show the EfficientNET-b0 classifying method based on the CNN Deep Neural Network classifier model meets the objective efficiently and produces a better accuracy performance outcome for classifying traffic signs data compared with other related methods which AlexNET and DarkNET-53, respectively. As a potential future work, for increasing knowledge about this classification issue, the amount of data on related algorithms may be changed to observe result variety better.

Declaration of Interest

The authors declare that there is no conflict of interest.

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Research Article

Designing of Dual Band F-Shaped RFID Antenna Using Machine Learning Techniques

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Abstract
In this paper, using machine learning, a dual-band F-shaped RFID antenna is designed to operate in 867MHz UHF and 2.45GHz WLAN bands. The study's dataset was consisting of a total of 625 samples, and this was received from the simulation software as a consequence of the parametric analysis of the design parameters for the antenna. The success of the algorithms was compared after six of the most popular machine learning algorithms were applied to the same parameters. The Random Forest algorithm, which has a 99.96% for R^2 score and a mean squared error value of 0.0004, has been used to predict the input port scattering parameter. With the best results obtained from this technique, the antenna operating at the desired frequencies was designed.
Keywords: Dual Band Antenna Design; Machine Learning; Radio Frequency Identification; Regression; Scattering Parameters.

1. Introduction

Machine learning technology advancements have kept pace with other technical advancements. in recent years and provide us with accurate results and evaluations by being used in many fields of study such as marketing, engineering, science, medicine, financial market analysis, etc [1]. On the other hand, UHF (860-960 MHz) band radio-frequency identification (RFID) systems have recently grown more appealing for a variety of industrial services, including supply chain, tracking, inventory management, and bioengineering applications. This is due to the system's ability to offer a greater reading range, faster reading speeds, and more storage space[2]. The developments in wireless communication technology have gained another dimension to the antenna, which is one of the most important elements of RFID systems, and antenna designs that can operate at different frequencies at the same time have arisen [3]. Antenna designs are realized with 3D simulation programs in a computer environment, the return loss and input impedance data of the antennas, gain values, and radiation patterns are examined in the simulation environment and appropriate designs are created [4], [5]. The performance of the antenna can be validated using simulation programs individually (in the environment of space) and systemic. On the other hand, as the antenna structure's complexity or system rises, the time required to achieve the desired antenna performance with these programs also rises proportionally to complexity [6]. For the design optimization of antennas utilizing computer-assisted simulations, several optimization algorithms are available in the literature and are easily adaptable. However, there is a basic drawback to these numerical algorithms since it takes numerous simulation cycles to identify an ideal design that can readily scale the design process [7]. Techniques have been implemented to reduce simulation time, and this implementation occasionally caused the verification of antenna performance to be limited. According to the most recent technical advancements, this simulation's runtime can be shortened by employing machine learning algorithms, and reliable outcomes that correspond to simulation data as well as real test data can be obtained [8]. Recently, computer-aided design methods using genetic and Ant colony optimization algorithms and artificial neural network (ANN) techniques have been applied for microwave modeling and system optimization [9]. Similarly, in these investigations [10], [11], the scattering parameter, design parameters, estimations of gain, and efficiency values were adjusted for the antenna design using machine learning approaches.

In Chapter 2, the selected single band F Shaped RFID antenna model's design parameters are discussed, along with the machine learning techniques that will be used to take these parameters into account. The performance statistics of six of the most popular machine learning algorithms are thoroughly detailed in Chapter 3. In Chapter 4, the performance of the dual-band F Shaped RFID antenna designed according to the optimum data obtained from machine learning techniques will be explained and the study's results are interpreted in Chapter 5.

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2. Materials & Methods

This section presents the selected Dual Band F Shaped RFID antenna's design parameters and provides details on the development process. Additionally, offered are machine learning models that predict scattering parameters for the suggested antenna design's UHF RFID and WLAN resonance frequencies. An accurate and properly formed data collection is required to apply machine learning techniques. This section also contains essential details regarding this dataset.

2.1. F-Shaped RFID Antenna Design

The selected Broadband Circularly Polarized Antenna with Square Slot antenna design was submitted by Jui-Han Lu and Sang-Fei Wang for UHF RFID reader applications [12]. This particular antenna is solely intended for use with the UHF band. The purpose of this paper is to determine the parameters that will operate this single-band antenna on both RFID and WLAN frequencies using machine learning techniques. Since numerous geometric parameters can be determined on this antenna, there are more inputs available for machine learning algorithms, which is why this antenna is selected. Figure 1 presents the parametric data for a selected antenna in detail.

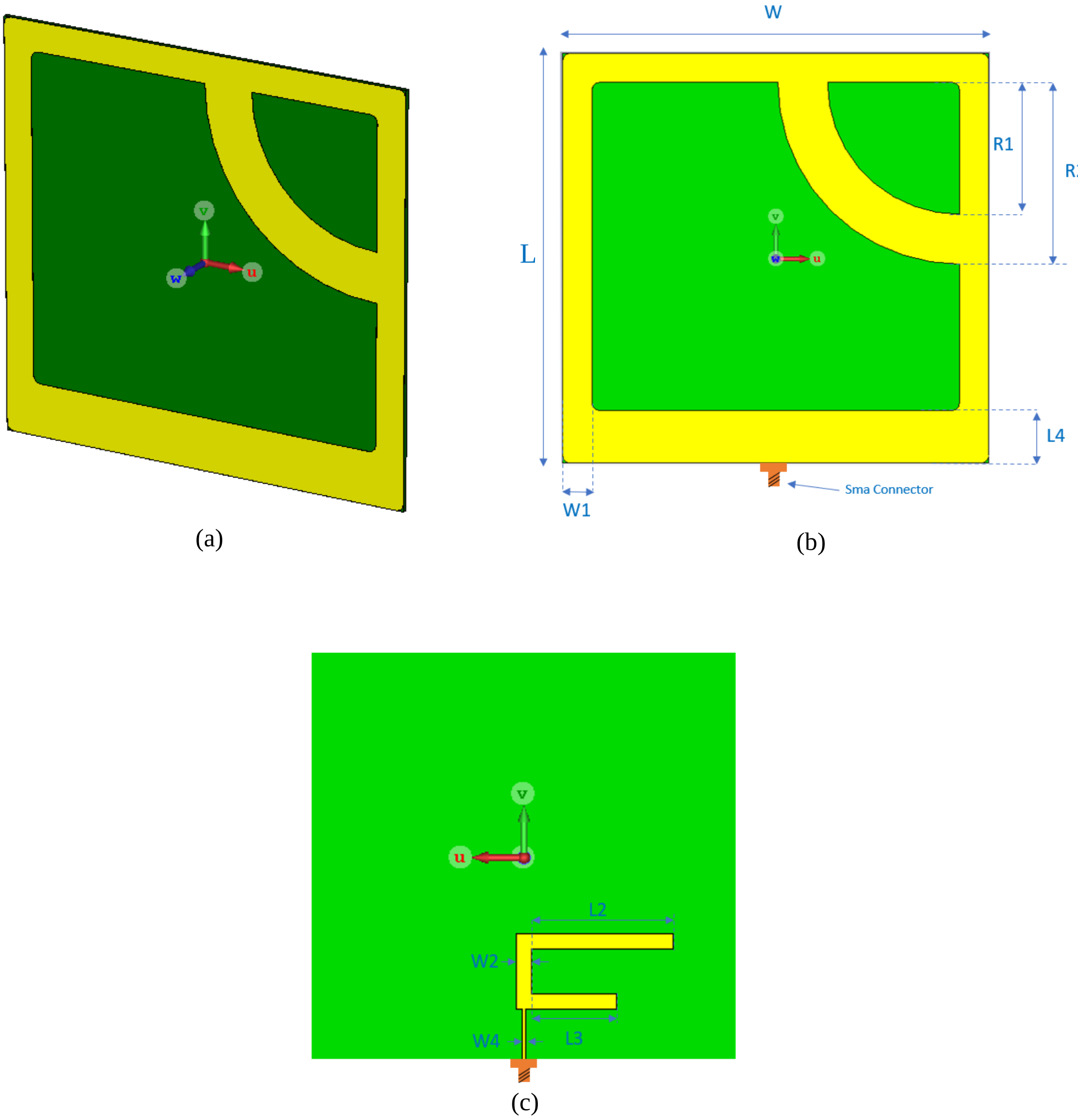


Figure 1. *Design of selected antenna; a) Antenna's top layer b) Antenna's top layer design parameters, c) Antenna's bottom layer design parameters*

The selected antenna with a total antenna size of 126x121 mm^2 is printed on a double-sided FR-4 substrate. This 0.8mm thick substrate has the following electrical properties ε_r=4.4, loss tangent value = 0.0245. Table 1 provides the design specifications for the selected antenna.

Table 1. *The Selected Antenna's Design Specifications*

Parameter	Value (mm)	Parameter	Value (mm)
L	126	W	121
L2	38	W1	15
L3	38	W2	6.2
L4	20	W4	1.48
R1	71	R2	62

2.2. Dataset Preparation for Machine Learning Algorithms

To estimate the input port reflection coefficient of the selected antenna in machine learning algorithms, a dataset is needed. First, to create this required data set, it was examined how the S_{11} graph of the selected antenna at the desired frequencies responds to the change of the geometric parameters on the antenna and the parameters to be used in machine learning were determined as W1, L4, R1, and R2. In addition, information such as step size, number of samples, and the change intervals of the determined parameters are shown in Table 2.

Table 2. *Antenna Design Parameters for Dataset Preparation*

Parameter	Change Rate (mm)	Step Size (mm)	Number of Samples
W1	[10 20]	2.5	5
L4	[15 25]	2.5	5
R1	[62 74]	3	5
R2	[45 60]	3.75	5
Total Data:			625

The input port scattering parameter of the antenna selected with the different design parameters specified in Table 2 was simulated in the 3D simulation environment and a dataset was created with the results. There are 625 samples total in the dataset, of which 20% are used for testing and 80% for training.

The Dual Band F-Shaped RFID antenna's simulation performance is realized using 625 data. The simulation program also yielded the following other sorts of scattering parameters: The scattering parameter's real (S_{11} Real), imaginary (S11 Img), and linear forms are selected as in the S_{11} machine learning model as output. The input and output values for the dataset were found to be appropriate for the regression algorithms used in machine learning after the examination.

Multiple-output regression techniques were utilized in addition to single-output regression types to evaluate performance because the simulation program generates different types of scattering parameters. The single output dataset was subjected to Random Forest, Gradient Boosting, Bayesian Ridge, and Polynomial Regression methods. Also, the voting regression technique, which may run many regression algorithms simultaneously was applied in addition to single regression performances, and performance comparisons were done.

3. Numerical Results

This chapter presents the performance metrics of the models that were created with machine learning techniques. The Python programming language was used to create the regression methods described in the preceding section, which were then used to apply to the necessary models and evaluated for performance metrics.

Random Forest, Bayesian Ridge, Polynomial, Gradient Boosting and Voting regression techniques were applied to the linear scattering parameter of the selected antenna, shown in Figures 2, 3, 4, 5, and 6 respectively. Figure 7 shows the Multi-Output regression technique. For the Real and Imaginary parts of the selected antenna's scattering parameter, since an output value is made up of two-part, the Multi-Output regression technique was applied. The graphs below show the actual and predicted values of these techniques based on 20 test data points.

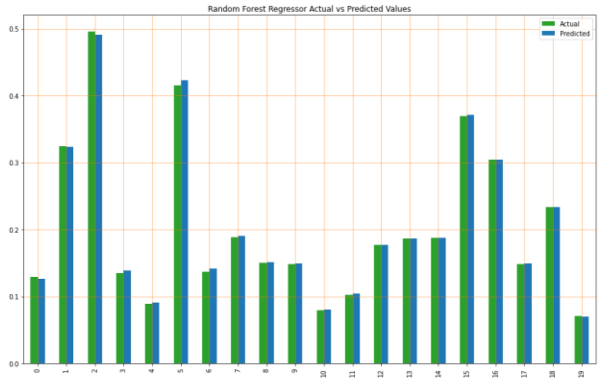


Figure 2. *Random Forest Regressor Actual vs Predicted Data*

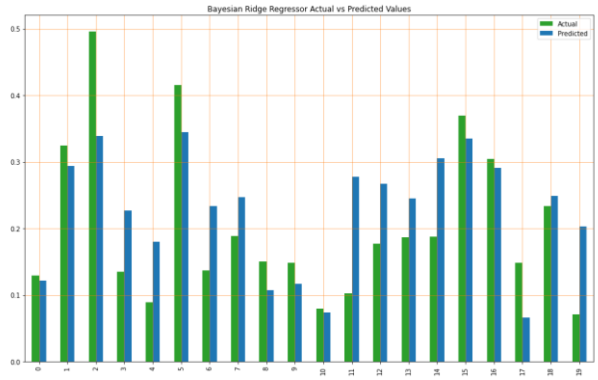


Figure 3. *Bayesian Ridge Regressor Actual vs Predicted Data*

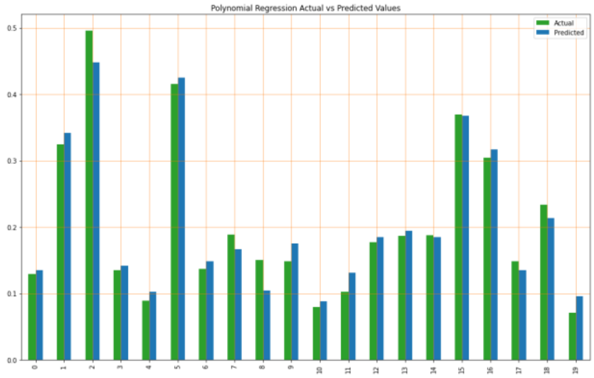


Figure 4. *Polynomial Regressor Actual vs Predicted Data*

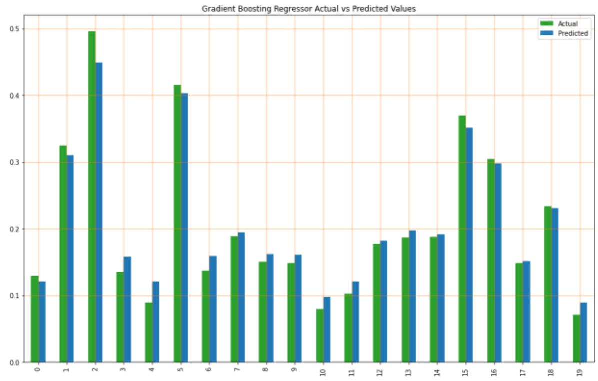


Figure 5. *Gradient Boosting Regressor Actual vs Predicted Data*

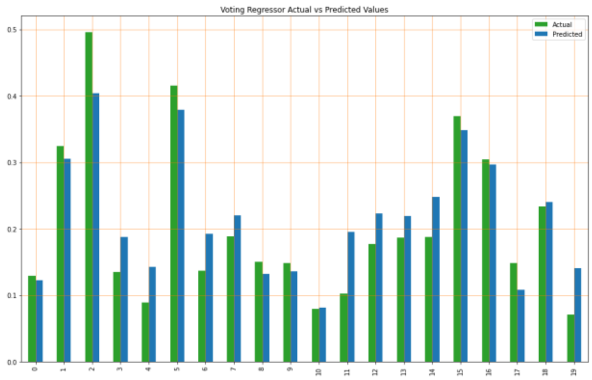


Figure 6. *Voting Regressor Actual vs Predicted Data*

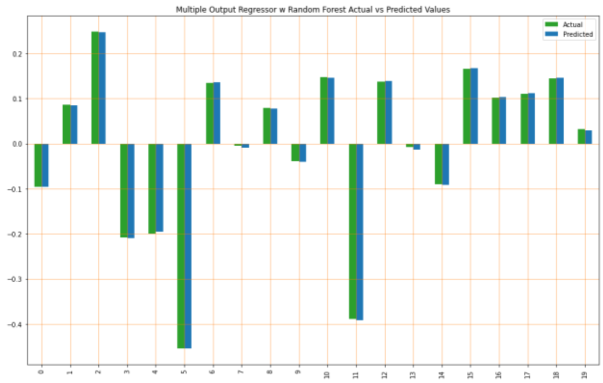


Figure 7. *Multiple Output Regressor Actual vs Predicted Data*

The Random Forest Regressor has the best prediction performance after the test data were analyzed, as shown in Table 3, which displays all the performance metrics.

Table 3. *Regression Methods Comparison Table*

(%)	Random Forest Regressor	Bayesian Ridge Regressor	Polynomial Regressor	Gradient Boosting Regressor	Voting Regressor	Multiple Output Regressor
R2 Score	99.96	57.49	98.56	97.52	87.56	99.95
Mean Squared Error	0.0004	0.622	0.0201	0.036	0.1820	0.0008
Root Mean Squared Error	0.214	7.886	1.148	1.904	4.266	0.2869
Mean Absolute Error	0.146	6.396	1.129	1.466	3.465	0.193
Maximum Error	1.749	22.97	6.995	6.301	11.68	-

To verify the success result of the Random Forest Regressor, estimations were made with five different parameters. The estimates are compared with the actual results and are shown in Table 4.

Table 4. *Random Forest Regressor Output vs Actual Result Comparison*

Input Parameters Freq (GHz), W1, L4, R1, R2 (mm)	Estimated Output Values (S_{11} Linear)	Actual Output Values (S_{11} Linear)
[2.4327, 10.0, 25.0, 71.0, 45.0]	0.19594009	0.195118490
[0.8734, 20.0, 25.0, 68.0, 48.7]	0.45746467	0.457240705
[0.8690, 10.0, 15.0, 68.0, 45.0]	0.06500955	0.064487627
[2.4552, 17.5, 17.5, 68.0, 60.0]	0.2428978	0.242507910
[0.8554, 20.0, 15.0, 66.5, 56.2]	0.49278992	0.50385024

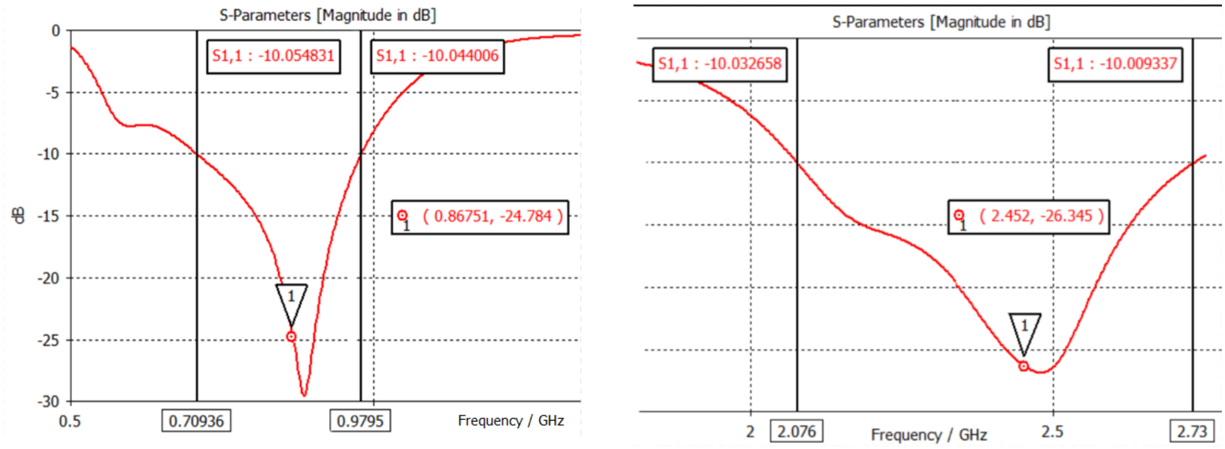
4. Designing of Dual Band F-Shaped RFID Antenna

With the model created with Random Forest Regressor, the most suitable parameters were determined for the dual-band F-shaped RFID antenna at RFID (867MHz) and WLAN (2.45GHz) frequencies. When the model was estimated using the intervals in Table 2, the most appropriate parameters for these frequencies considering input port scattering parameters are shown in Table 5.

Table 5. *Dual Band F shaped RFID Antenna Parameters & S11 at 867 MHz and 2.45GHz*

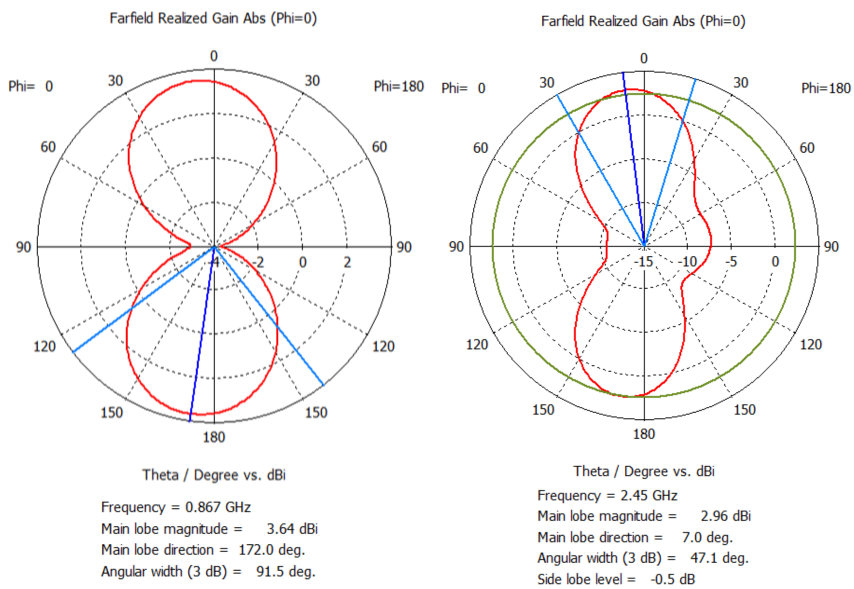
Parameter	Value (mm)	Estimated Output Values (S_{11} dB)	
W1	10	867MHz	2.45GHz
L4	18	-25.16	-25.95
R1	62		
R2	45		

The simulation environment was used to run simulations using the parameter values listed in Table 5. Input port scattering parameters and gain results are shown in Figure 8 and Figure 9, respectively.



(a) (b)

Figure 8. *Input Port Scattering Parameter of Dual Band F-Shaped Antenna at a) 867MHz b) 2.45GHz*



(a) (b)

Figure 9. *Gain of Dual Band F Shaped Antenna at a) 867MHz b) 2.45GHz*

5. Conclusion

This work examines the performance metrics of different machine-learning approaches to estimate the scattering parameter of the selected F-shaped RFID antenna. A dataset with 625 samples was obtained after the antenna's design parameters were modified parametrically and in relation to one another. The dataset was split into a training and test dataset, and the accuracy of various machine learning techniques was evaluated. The model with the highest accuracy rate was the Random Forest Regressor, which has a 99.96% for R^2 score and a mean squared error value of 0.0004. The antenna working in the UHF band was redesigned to work in both the UHF and WLAN bands. As a result of the study, an antenna that can operate in both UHF and WLAN bands with bandwith about of 270MHz at UHF and 700MHz at WLAN has been designed.

Declaration of Interest

The authors declare that there is no conflict of interest.

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Research Article

A Novel Color Detection Model

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Abstract
In today's world, the consumption of clothing and accessories is increasing day by day. In this consumption area, people sometimes have difficulty in finding a color outfit or jewelry they want. Especially in face-to-face shopping, people look at all the stores to find the color they are looking for and consume a lot of energy in those stores. Considering this increasing problem, a model is proposed in this study that detects color and then displays the images of the clothing and accessory data it contains according to the color it perceives. In this way, this model provides ease of finding what people are looking for. Therefore, it could be easily stated that this system turns the filtering process into a kind of visual filtering. The results derived using the proposed model prove its effectiveness for detecting the colors.
Keywords: Clothes; Color Detection; Filtering.

1. Introduction

In today's conditions, clothing and accessories consumption is increasing. This increased consumption can make people to have difficulty in finding a color outfit or jewelry they require which in return causes a lot of energy and time consumption. Considering this problem, a model detecting the color of the clothes and accessories required and then displaying the images of the clothing and accessory data it contains according to their color is developed in this study. It could be easily stated that color is the significant feature for our proposed model. Human eyes and brain work in coordination to convert light into color, and light receptors in the eyes transmit the signal to the brain, which in turn recognizes color. Adapting this strategy to the machines is the key factor in identifying the color names in the developed model and fulfilling its main task [1][2]. To express the color of some pictures, Red, Green, Blue (RGB) based color recognition system [3] is used. In this system, each color always consists of 3 values between 0 and 255 followed by RGB [3]. In the literature, there are some models relying on this system, for instance; Lee et. al. [4] applied the color identification technique for the NOKIA smart mobile device. This system uses phone cameras to recognize colors. This system's disadvantage is to only use three basic colors (red, green, blue) [5]. Duth et.al. shade and model images in the color detection system proposed in [3].

Contrary to the existing systems in the literature, using RGB in our proposed model is not efficient. The reason behind this is that it is desired and aimed to detect the color of a currently displayed image and to show its color in our model. Various filters have been tried in our model to make the RGB method compatible with the system, for example, Laplacian However, the desired yield could not be obtained. For the system to obtain images in the desired direction, the HSV in OpenCV method is used in our proposed study. There are red, green, and blue colors in the HSV method but in addition to these there are H, S, V. In HSV, color can be changed with 'H', saturation can be changed with 'S', value can be changed with 'V' [6]. This makes it easier to adapt the system to real life. Another reason for using this method is that the CCD camera used to define color in more complex systems is not used. The abbreviation for this camera is device with charging connection. Cameras with such image sensors perform well in low light conditions [7]. But in the proposed system, the webcam is used to detect the object. In the presented project, using the HSV method, the color ranges and the color of the objects are determined more efficiently.

In our proposed model, another important factor other than color is to save the data in the system and display it on the screen. The filing method was used to make this happen. With this simple and time-saving filing (dataset) method, the desired images are displayed on the screen according to the colors. As a result, a webcam is used to model real-life objects, the colors are determined by the HSV method to detect the colors of these objects and display on the screen, and a window is created using some libraries in Python. Colors can be printed on the screen with OpenCV. Finally, the requested data is displayed with the file system.

The remainder of the article is organized as follows. The model proposed is introduced in the second section. The proposed model is discussed in section 3. In section 4, the results are presented. Finally, in section 4, conclusions and considerations for future work are presented.

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2. Proposed Model

Our proposed model's framework can be visualized in Figure 1. As can be observed from the framework, OpenCV and NumPy libraries have an important place in the working algorithm of our proposed system. The reason for using these libraries is that they are useful for image processing. NumPy is also widely used for multidimensional arrays and mathematical operations, which are frequently encountered in image processing.

As can also be observed from Figure 1, after importing the OpenCV and NumPy libraries, a video capture method is created in our proposed framework. The reason for this is to be able to capture and detect the images in the video recording. While creating this, the size of the frame of the capture screen is also adjusted. After this stage, methods are defined to detect colors. Following these defined methods, it is necessary to open a color palette to define the colors. However, before the Color palette is defined, the HSV technology, which is used to better detect the color of the objects, is created. By looping this technology, HSV ranges are defined, and masks are created. Later, the created management system is tested with every color registered. After this stage, the palette for the colors to be used in the system is opened using the cv2 color method. Then, it is time to determine how the image we want to be detected would be detected by the camera. For this, a point is specified in the middle of the screen. The camera is defined as a round value and set to the middle of the camera. In this way, the objects shown to the point appearing in the middle of the screen can be detected. After detecting the object with the camera, the process of detecting colors is started. Numbers between 0 and 255 corresponding to the colors are used here. The range is determined for each color. Colors corresponding to numbers could be defined thanks to the cycles defined in the system. After determining the color of the detected objects, the putText method is used to display the detected colors on the screen. When it comes to the final stage of the project, it is requested to display a visual on the screen according to the colors. For this, images are displayed on the screen by using the circle method. Finally, the system is terminated with the release and destroyAllWindows methods so that the video from which the video is taken will not continue.

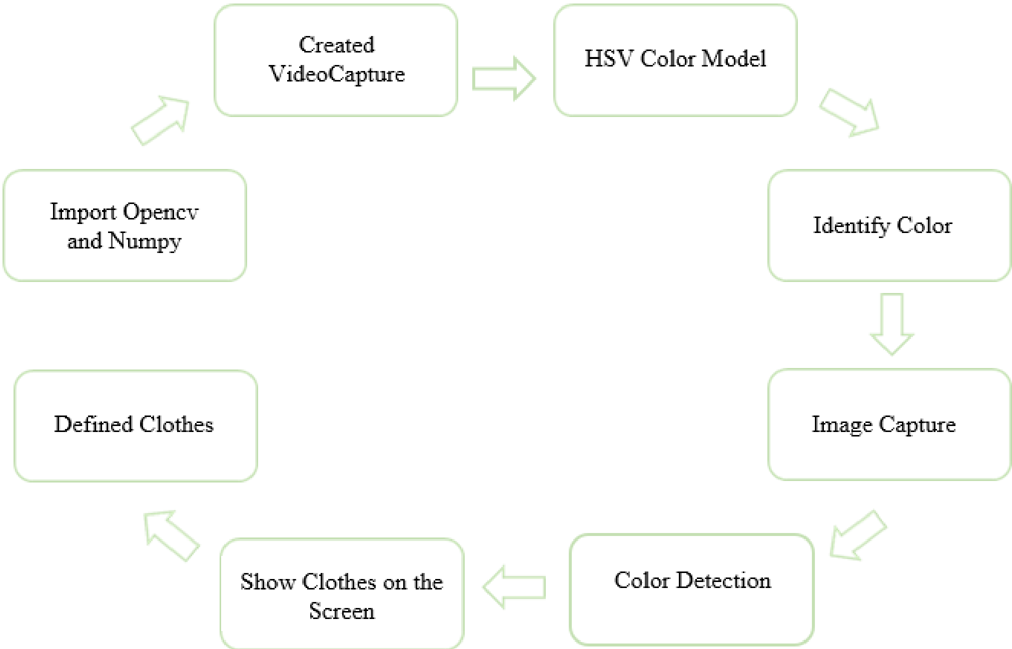

Figure 1. *The framework of the proposed model*

In addition to all these processes, the idea of transferring data from files is studied when displaying the data as seen in Figure 2. Then, a dataset is created as seen in Figure 3. The pictures that are requested to be included in this created data set are positioned according to their colors and then called from the system. In this way, the desired images are displayed on the screen when the colors are detected.

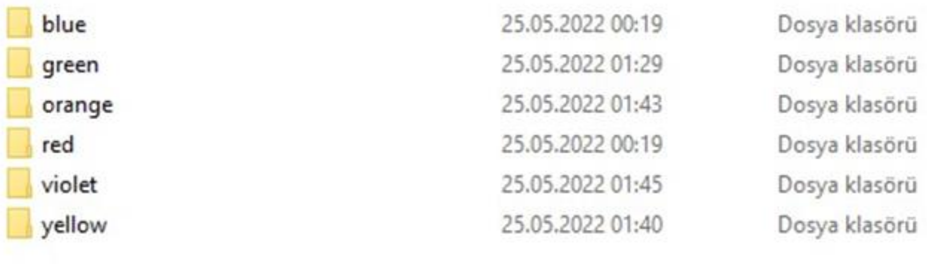

Figure 2. *Filling Method*

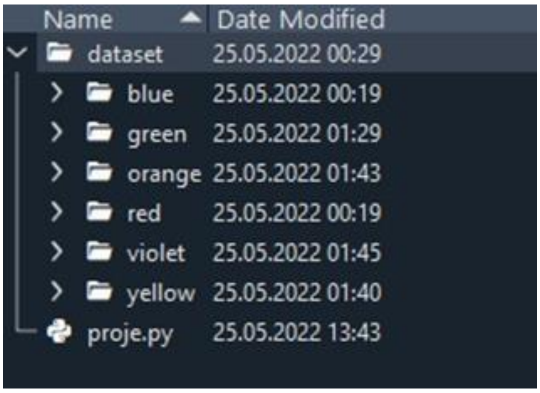

Figure 3. *The dataset in the proposed system*

3.Results and Discussions

In order to derive results, the RGB method is first used for the color detection. With this method, different and inefficient results are obtained for our system as exemplified in Figure 4. For example, as seen in Figure 4, when run for orange color, data [0 94 254] is received. So 'Green' is 94. In this method, each pixel has the same value. Although there is no problem with still images, it is not useful as the aim of the project is to capture real-life images at that moment. Because this method simply mixes the colors and identifies the presence of each by showing the resulting color. So, RGB method is converted to the HSV method to obtain results with our proposed method.

Figure 4. *The end obtained from the RGB method*

In our proposed model, another important thing to mention is the camera point, which plays an important role in perceiving the color of the image. The biggest disadvantage with this is that the color detection capacity of the camera is different due to the image quality. For example, it may detect a distant white object as blue due to camera quality. Therefore, it can actually display images of unwanted colors. For example, when it detects a white wall in a distant and illuminated environment, it can print it in blue on the screen. This is a negative result we get. However, to minimize this and get efficient results, we convert RGB to HSV and we receive the results we want. The results screen of our proposed model can be seen in Figure 5. With the HSV Color Space method used later, we use a filtering method so that the system can more easily focus on the object whose color is desired to be detected. In this way, the screen is blacked out of the object and become more efficient. Color-focused results can be observed in Figure 6 and Figure 7. As a result, when we bring an object other than Camera quality to the screen, the system works properly, with our last try, it focuses on the object better, the color of the piece corresponding to the point is displayed on the screen, and the relevant pictures are displayed on the screen. The result is about the registered colors we add to our filling system.

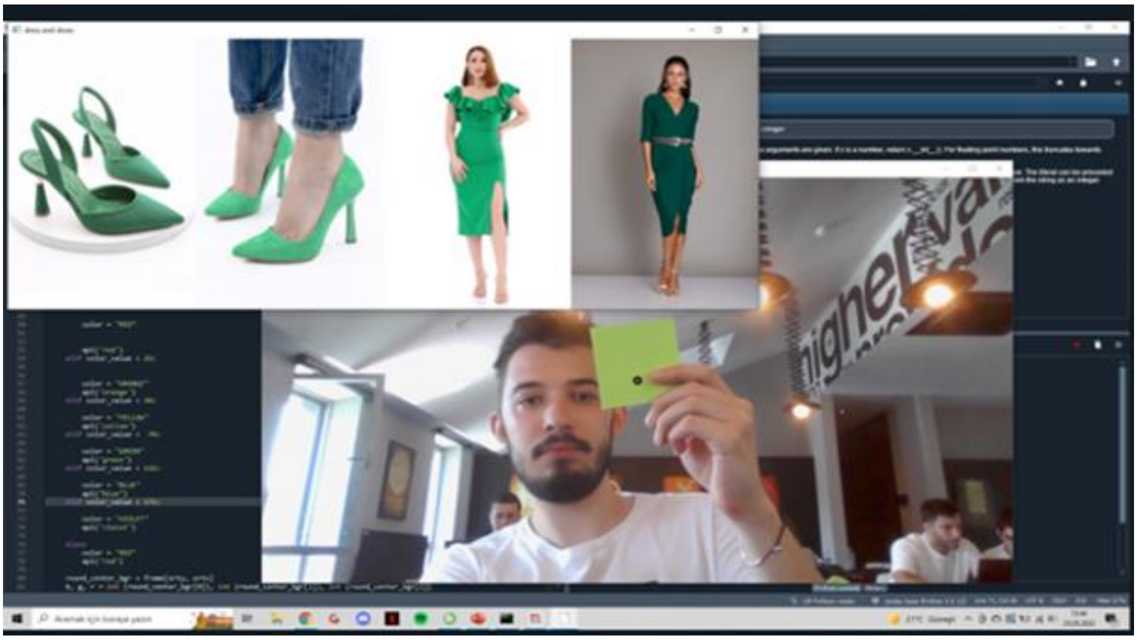

Figure 5. *First trial screen*

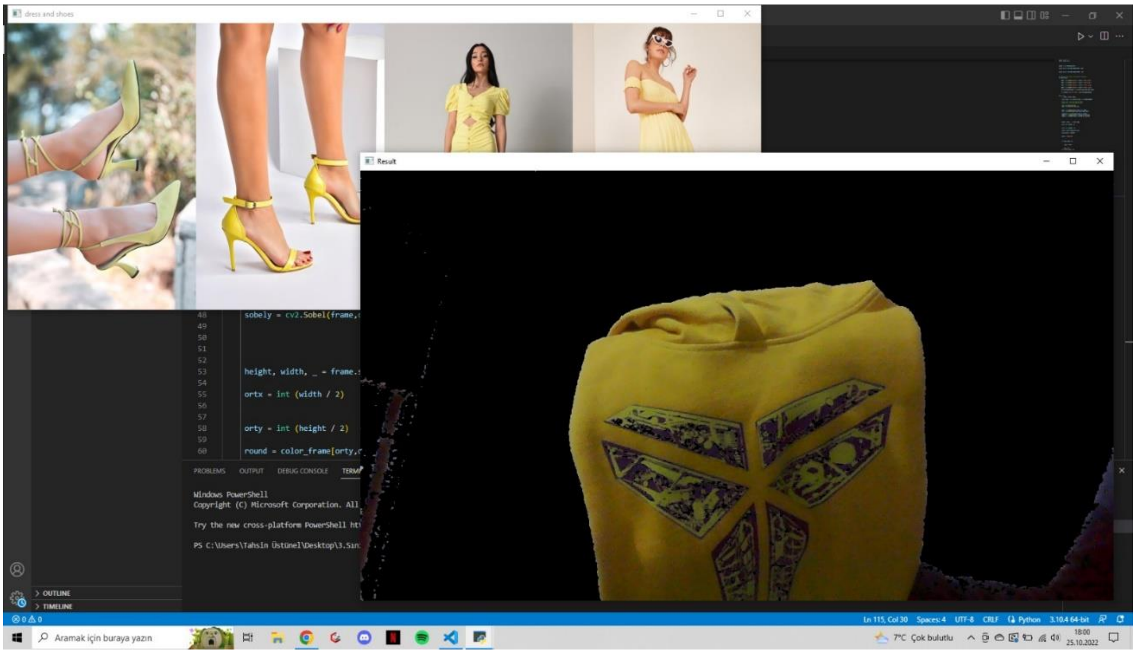

Figure 6. *Color-focused result with HSV*

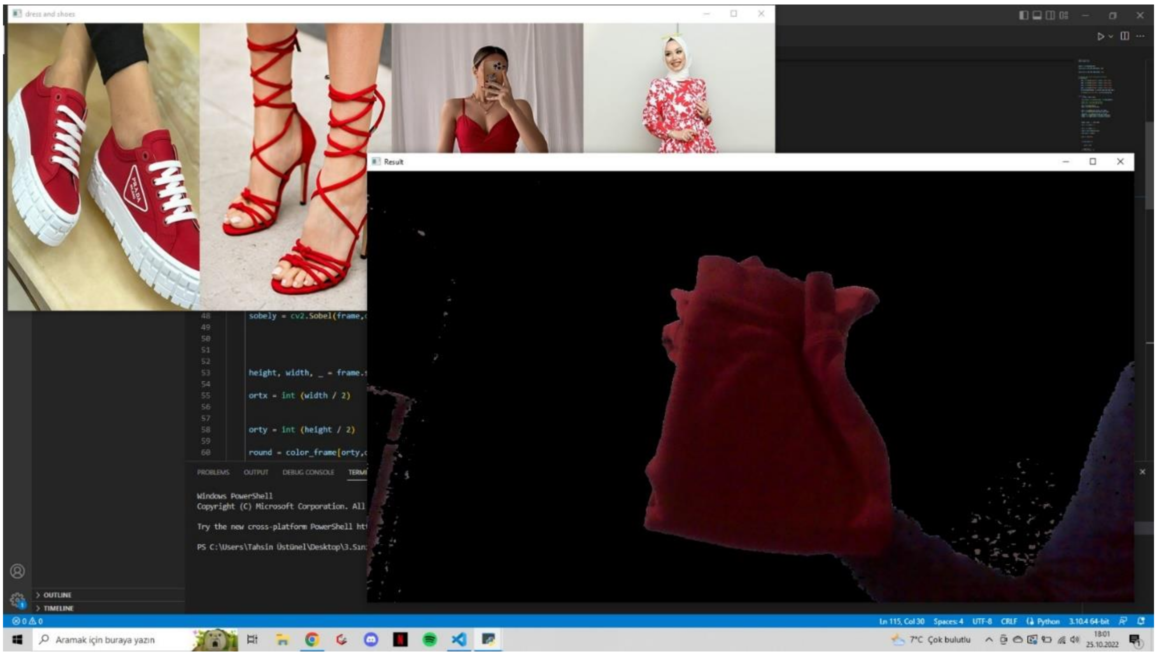

Figure 7. *Color-focused result with HSV*

4. Conclusions and Future Work

In this study, a model that brings images of clothes and accessories according to the desired colors has been proposed. The wealth of the Python-OpenCV libraries have been used in the proposed study. In addition, the differences and usage areas of the methods used in color perception and the areas where they are efficient have attracted attention. Along with the results of the proposed model, different color detection models and filtering processes are also observed to prove the effectiveness of the proposed model. The results of the proposed model have been observed as desired compared to the different color perception models.

There are many ways that can be done in the future to make this app useful in real life. For this application, high resolution cameras that are more sensitive and adaptable to environmental conditions can be used. In order to expand the color range, more color ranges can be added to the system and tested one by one. In addition to these, the data system can be supported with database systems so that it can be integrated into a more complex system. Thanks to this database support, it can even be transformed into a system that proposes combinations for users who use the application. At the same time, different filter features can be tried to add color to the application. Like outlining the clothes other than dimming screen. As a result of all these, it can be turned into a system that can be used in stores in the future. In other words, a user who shows the color he wants to the camera can see all the clothes with that color and even the content that is compatible with it and can easily choose it.

Declaration of Interest

The authors declare that there is no conflict of interest

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Research Article

Machine Learning Predictive Wi-Fi Antenna Design for Wireless Communication Technologies

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Abstract

The use of the Internet has become indispensable with the developing technolog. Antennas are the most important stage to access the Internet. Recently, development studies have increased considerably for antennas, which are the first step of wireless communication technology. In this study, a Wi-Fi antenna design with 2.4 GHz operating frequency that can be used in wireless communication technology has been realized. The designed antenna has dimensions of (Length) 90- (Width) 70 mm. It is very small size is very advantageous in terms of use. Microstrip antenna has been chosen to meet the necessary needs. While designing the antenna, CST Microwave Studio program has been used and numerical calculations have been made. After the antenna design has been made, machine learning support has been provided. The most appropriate return loss estimation has been made according to the selected algorithms. The most effective lengths of the antenna have been determined and parametric analysis has been performed. The results of the selected algorithms have been observed. Based on these results, the algorithm that made the closest prediction has been determined. As a result of this study, an antenna design with a return loss value of 21 dB and a bandwidth value operating between 2.37 GHz - 2.42 GHz frequencies have been carried out. The designed antenna is acceptable according to IEEE 802.11 standards. Decision Tree gave the best prediction result according to machine learning algorithms.

Keywords: Antenna Design; Machine Learning; Microstrip Patch, Wi-Fi.

1. Introduction

Recently, the use of the internet and wireless communication technologies have increased tremendously, so the need for antennas to be used in this technology has increased so much [1]. One of the most important examples of wireless communication technology is WLAN (wireless local area network) systems [2]. It includes Wi-Fi antennas with 2.4 GHz operating frequency within WLAN systems. Antennas are one of the microwave components that are always open to improvement and innovation. Recently, studies on microstrip antennas have increased considerably [3]. Improvement and development studies on microstrip antennas have become quite common. High performance antennas are needed in this area. In his study, Palandöken deals with the new antenna design method based on artificial materials. The substrate or radiating part of the antenna as a solution for better antenna designs is described, from basic electrical limitations to proposed design solutions [4]. At the beginning of antenna improvement studies, dimensional changes in designs come first. Designing a small size antenna will make it cost effective and compact [5]. Ghouz et al achieved a moderate gain (6.0 dBi) at 38 × 36 mm2, a satisfactory efficiency (81%). The proposed antenna is of simple designs and compact dimensions and can be used for many wireless applications including Wi-Fi, LTE and WiMax [6]. It has been done in studies that the usage area of the antenna is valid for many frequencies. Patel et al. designed a multiband antenna operating at frequencies of 2.47–2.54GHz, 4.14–4.23GHz, 5.43–5.78GHz and 6.71–7.42GHz [7]. Another development work is to change the antenna geometry and create slots on the antenna [8]. Raad H. Thaher and Zainab S. Jamil did parametric studies on the antenna and drilled slots in certain areas. The antenna they designed works in 2.4/5.8 GHz bands for Wi-Fi/WiMAX applications. The results of return loss are 32.77 dB at 2.4 GHz at 7.4% bandwidth and 25.955 dB at 5.8 GHz with 8.17% bandwidth [9]. In order to provide machine learning support after the antenna design has been made, Misilmani et al. conducted a study covering the main aspects of machine learning, including the basic concept, differentiation with artificial intelligence and deep learning, learning algorithms, broad applications in various technologies, with a focus on its use in antenna design [10]. Antennas have a certain frequency range to operate. IEEE 802.11 standards have been taken into account while determining the frequency ranges. IEEE 802.11 standards are the general name of the developed wireless networks [11]. 802.11 standards represent protocols created over WLAN within the local network. This standard has been also taken into account

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in this study. In the designed antenna, it is aimed to design the most suitable microstrip antenna in terms of return loss and antenna gain. After the design has been carried out, the results of the machine learning algorithms have been observed.

The paper is structured as follows. In Section 2, a discussion will be made about the design of the designed antenna, its dimensions, and the preferred application for simulation. In Section 3, simulation results of the designed antenna are presented. In the last section, section 4, the general summary of the study is explained.

2. Material and Methods

2.1 Designing the Proposed Antenna

While designing the antenna, micro strip antenna has been preferred due to its geometry, lightness, low production cost and compactness [12]. Microstrip antenna has 3 important layers. These are Ground - Patch – Substrate. The ground part of the designed antenna is made of copper and its thickness is 0.035 mm. This layer is conductive. The substrate layer is the second layer. FR4 material has been chosen for this layer. Its dielectric coefficient is 4.3 and its thickness is 1.6 mm. This material is generally preferred in antenna designs. The dimensions of the substrate-Patch layer (Length) are set as 90 mm- (Width) 70 mm. The last layer where the radiation takes place is the patch part [13]. In this part, it should be conductive like ground. Copperis used in the patch part of the designed antenna and its thickness is taken as 0.035 mm. While the data have beentaken for machine learning, the parameters that have been modified on the Patch are determined from this section. While determining the parameters, values have been taken from various parts of the antenna, but the 3 selected parameters are the ones that have the most impact on the antenna. Therefore, machine learning has been done over these 3 parameter changes.

2.2 Antenna Feed

There are many feeding methods to be used when designing the proposed antenna [14]. According to thedesign, the most suitable feeding method has been selected as microstrip feeding. A more suitable value has beenobserved in this feeding method compared to the others. The input impedance between the antenna and the supplyline should be normalized. The normalized input impedance result is 50 ohms [15]. This value is the internationally accepted value [16]. Important for proper integration of antenna and feed line.

2.3 Simulation of Proposed Antenna

CST microwave studio program has been used in antenna design. The antenna designed as a result of the simulation is shown in Figure 1. The parameters entered during antenna simulation are shown on the figure. It is shown on the antenna in the port where the feed line is used.

2.4. Machine Learning Algorithms in Proposed Antenna

In order to design the antenna based on machine learning, 3 different parameters have been selected over the antenna. These 3 selected parameters are the most effective parameters for the antenna. The first parameter (P1) had the most influence over the feed line width. The second parameter has been on the slit width at the ground of the antenna (P2). The third parameter has been taken over the width of the patch part of the antenna (P3). Parametric analysis has been performed with 125 parameters of 5x5x5 and the return loss values have been recorded.

3. Results

The results of the simulations of the antenna designed in the CST microwave studio program are examined. The return loss, gain and radiation pattern graph required for the antenna are given below. Machine learning regression results are shown.

The return loss value of the designed antenna has been observed according to the CST simulation program. S parameter result is shown in Figure 2. The return loss of the designed antenna is 21 dB. The operating frequency range is 2.37 GHz - 2.42 GHz. This operating frequency range and return loss value are in acceptable standards.

The gain of the proposed designed antenna has been obtained as 0.627 dBi as seen in Figure 3.

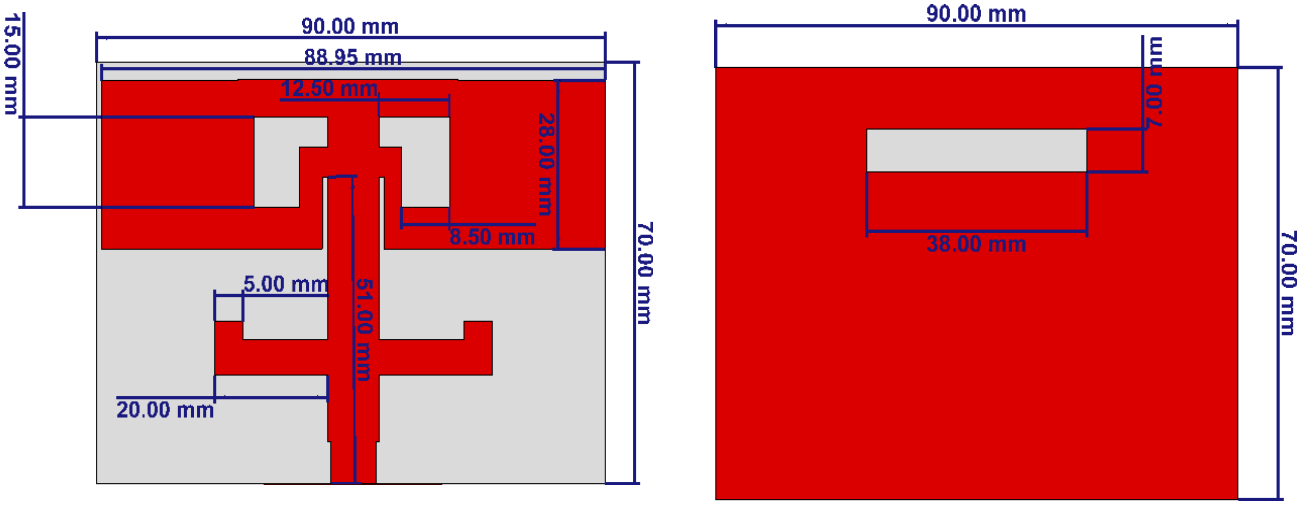

Figure 1. *Proposed Antenna Design Front and Back View*

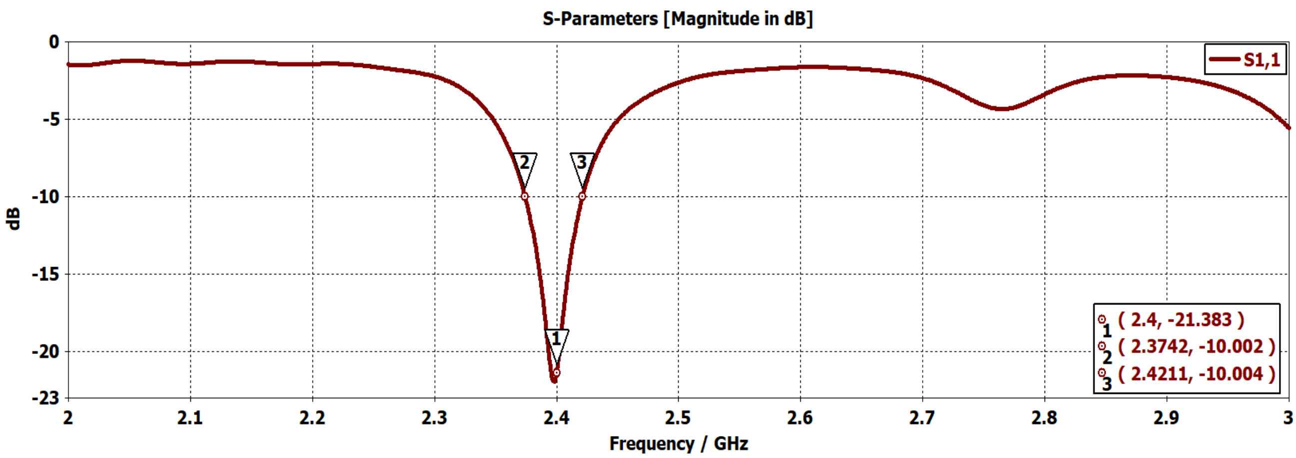

Figure 2. *Return loss result of proposed antenna*

Machine learning code has been written. 4 different algorithms have been selected. The selected algorithms are shown in Table 2. In machine learning, the data has been used for 30% learning and 70% testing. The estimation process has been carried out through the algorithms that completed their learning. According to the results obtained from the antenna designed, the Decision Tree Regression algorithm gave the best result out of the 4 regression models available.

It has been seen that the Decision Tree algorithm gave direct results when any random value has been selected from the data set. Although the machine learning algorithm learned these valuescompletely, when a value has been selected from 70% of the data set, it still made the best guess, considering thatit did not learn any data. When the parameters that are not used in machine learning are entered on the antenna (the values in Table 1), the return loss result value is shown in Figure 4. Accordingly, when the value has been taken from the user and predicted by machine learning, the decision tree algorithm gave the best result. This situation observes in Table 2 that he made the closest estimate here. When asked to predict a value that is not in the data set, any 3 values have been taken from the user and the result has been compared with the correct result. Accordingly, decision tree regression madethe best guess. The values received from the user are shown in table 1, the result and the estimation results are shown in Table 2.

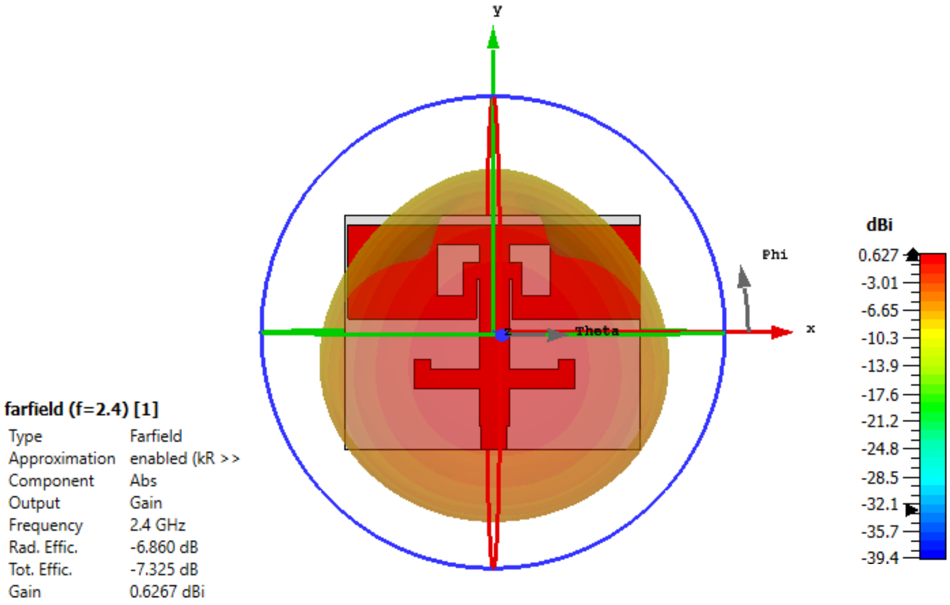

***Figure 3**: Radiation Pattern Result of Proposed Antenna*

Table 1. *Proposed Antenna Selected Parameters Values*

SELECTED PARAMETERS	SELECTED PARAMETERS VALUES
P1	2.5
P2	1.5
P3	4

Table 2. *Proposed Antenna Machine Learning Results*

Machine Learning Algorithms	Prediction of Return Loss Value
Polynomial Linear Regression	-10.142 dB
Random Forest Regression	-17.009 dB
SVR	-7.5001 dB
Decision Tree	-15.6028 dB

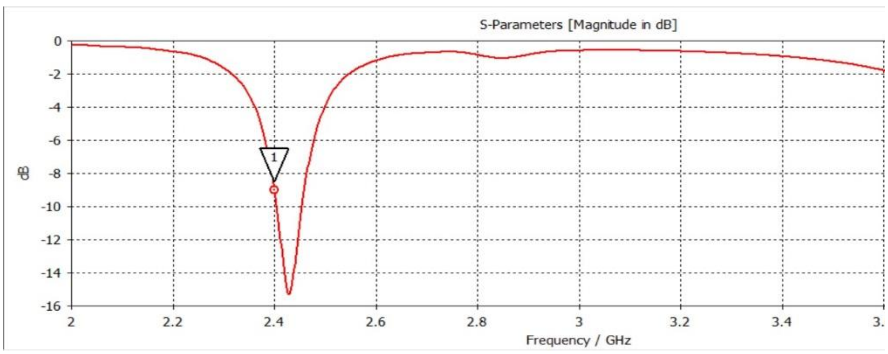

***Figure 4**. S Parameter Result*

Declaration of Interest

I declare that there is no conflict of interest.

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Research Article

Diagonal L-Shaped Slotted Antenna Design for 2.4 GHz Wireless Applications with Machine Learning Based Reflection Coefficient Calculator GUI

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Abstract
In this study, a machine learning assisted microstrip antenna design for a 2.4 GHz Wi-Fi frequency band has been designed and numerically calculated. The proposed antenna design has been carried out using an electromagnetic field solver CST, different design parameters have been determined and because of parametric calculation, data suitable for machine learning algorithms have been obtained. According to the different values of 4 design parameters, 625 different antenna reflection coefficients at the 2.4 GHz frequency band were obtained in linear and decibel forms for the machine learning-based design. 4 different machine learning regression algorithms (linear regression, support vector regression, decision tree, and random forest) have been used to estimate the reflection coefficient at 2.4 GHz. The machine learning results have been examined, it has been achieved that the best prediction performance model had R2 value of 0.8 and a mean squared error value of 0.2 for the S11 in dB form, and R2 value of 0.98 and a mean squared error value of 0.02 for the linear S11. In addition, a PyQt based graphical user interface is presented, which can instantly estimate the reflection coefficient with different machine learning techniques depending on the design parameters of the proposed antenna.
Keywords: Microstrip Antennas; Antenna Design; Wi-Fi Technology; Machine Learning; Regression Algorithms; GUI Design.

1. Introduction

With technology development, the importance of wireless communication technology has increased significantly. Also, in recent years, the rapid developments in technology have also led to an increase in the variety of modern devices in which wireless communication technology has been used [1]. One of the most essential parts of these wireless systems is antennas. The increase in the variety of modern devices using wireless communication technology makes it necessary to design compact antennas [2]. In recent years, microstrip antennas have become more popular and are increasingly being used in many fields because they have characteristics such as light weight, ease of production, and low production cost. For this reason, microstrip antennas are often preferred in the field of wireless communication technology [3]. Microstrip patch antennas for home, office and industry are among the many bands used in mobile systems used in their applications; the ISM (Industrial, Scientific, and Medical) band, which covers the range of 2400-2485 MHz, is the most widely used. A wireless network developed by the Institute of Electrical and Electronics Engineers, IEEE, Wireless Local Area Network (WLAN) the general name of the standard is IEEE 802.11, and the WLAN standard operating in the ISM 2.4 GHz band is defined as IEEE 802.11b and IEEE 802.11g [4]. Microstrip antennas consist of the radiation layer, the dielectric layer, and the soil layer. The underlying soil layer is conductive, and it allows microstrip antennas to emit one-way radiation. The middle layer consists of a dielectric material and ideally, its dielectric constant must be less than 2.5. In dielectric material, the thickness varies from 0.05 mm to 6.35 mm. The thickness of this layer and the dielectric constant directly affect antenna parameters such as radiation values and bandwidth. To improve the performance of the antenna should be selected the low dielectric constant and a thick dielectric layer. The top layer is usually made of gold, silver, or copper it is the conductive layer for the antenna emitting radiation. Its thickness varies from 0.035 mm to 0.070 mm [5].

In recent years, machine learning has been used in many fields: automotive, medical, entertainment, marketing, speech recognition technologies, and much more [6]. Machine learning is a subset of artificial intelligence that aims to create a mathematical model using known input and output data [7]. Machine learning algorithms can be divided into 4 categories, each of which is designed for a different purpose. For example, supervised learning is intended to scale the scope of data and make predictions based on it. On the other hand, unsupervised algorithms organize and filter data to make sense. Machine learning algorithms are supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning. In the last decade, machine learning algorithms have been widely used to adapt not only antenna designs but also many microwave components more easily and

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increase performance [2, 8 - 11]. The electromagnetic field solver used in this process meets the need to produce the exact results, but these solvers cause a lot of time to spend on the antenna design process. Also, antenna designs developed using machine learning are expected to produce faster and more optimized results. Because, using the dataset obtained from the proposed antenna, thousands of results of the proposed antenna can be estimated. The same results can also be calculated using electromagnetic simulation programs, but this becomes difficult because it will take a very long time [6].

The paper is established in the following manner. The antenna model parameters and numerical calculation results of the proposed antenna are explained in Section 2 with the machine learning assisted design. The numerical results of the machine learning assisted design are given in Section 3. The concluding remarks are conducted in Section 4.

2. Methodology

2.1. Diagonal L-Shaped Slotted Antenna Design

The geometrical configuration of the proposed antenna in this study is given in Figure 1. The proposed antenna has a resonance frequency of 2.4 GHz. This frequency band is used as the Wi-Fi frequency band, according to IEEE 802.11 standards. To reduce the cost of the developed antenna design, FR-4 material has been selected as a substrate. The FR-4 material used has a thickness of 1.6 mm, a dielectric constant of 4.3, and a loss tangent of 0.02. Copper has been used with a thickness of 0.035 mm for the antenna radiation and ground layers. The geometric dimensions of the proposed antenna are given in Table 1.

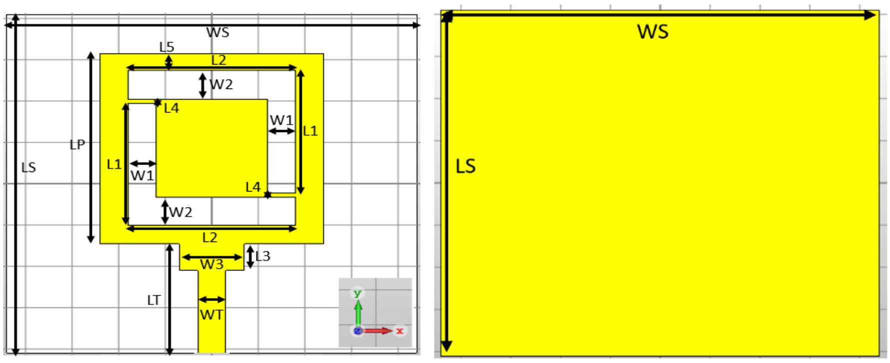

Figure 1. Front View and Back View of Proposed Antenna

Table 1. Dimensions of Proposed Antenna

LS	**LP**	**LT**	**L1**	**L2**
41 mm	23 mm	13.2 mm	14.8 mm	18 mm
L3	**L4**	**L5**	**WS**	**WP**
3.2 mm	0.5 mm	2 mm	44 mm	24 mm
WT	**W1**	**W2**	**W3**	
3 mm	3 mm	3.5 mm	7 mm	

The method of feeding microstrip antennas affects the performance of the antenna such as bandwidth, antenna gain, and antenna reflection coefficient. Basically, microstrip feeding, coaxial feeding, coplanar waveguide feeding, proximity-coupled feeding, and aperture-coupled feeding [12]. The antenna design developed is fed using the microstrip line feeding method. The design process of the proposed antenna is carried out using CST Studio Suite Electromagnetic Field Simulation Software. Also, important parameters of the antenna have been examined. The reflection coefficient result (S_{11}) of the proposed antenna design developed is given in Figure 2.

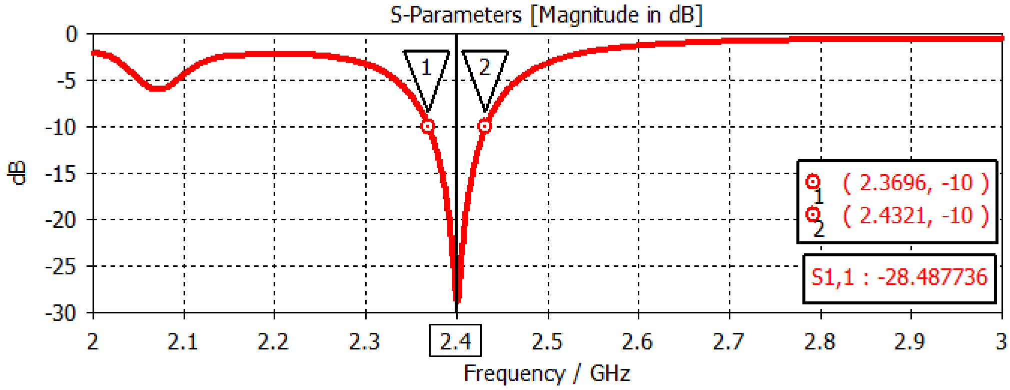

Figure 2. S_{11} Parameter of Proposed Antenna

2.2. Machine Learning Assisted Antenna Design

The following steps should be followed when performing machine learning-assisted optimization in antenna design. First, an antenna design should be developed. Then, using electromagnetic simulation programs, multiple number simulations of the antenna design developed by changing the different design parameters of the antenna should be performed. In this case, the electromagnetic characteristic of the antenna is obtained. Later, various machine learning algorithms should be developed for use in antenna optimization. Finally, the machine learning algorithms that have been developed are trained using the data that has been obtained [12]. As a result, the estimation of the antenna's performance can be performed without the need for electromagnetic simulation programs. Thus, antenna optimization can be achieved in less time.

Many machine learning algorithms are used in the field of antenna design, the most used algorithms are supervised algorithms [8]. In this study, more than one machine learning algorithm has been developed. These are linear regression, support vector regression, decision tree, and random forest. In addition, polynomial regression is added to the developed algorithms. The relationship between variables in the dataset may not always be linear. In such cases, it may be useful to apply to polynomial regression. So polynomial feature option has been added to the developed algorithms. At the training stage, more accurate prediction results can be obtained using the transformed dataset by selecting the desired polynomial degree. Also, an interface design has been developed using PyQt Designer to provide more comfortable use for the user about antenna optimization. The interface design shown in Figure 3 includes the following: 4 different machine learning algorithms, training can be done by adding the desired level of polynomial feature for the desired algorithm, and the training results for the desired algorithm can be displayed instantly at the desired polynomial degree and the reflection coefficient of the proposed antenna can be estimated for specific design parameters values.

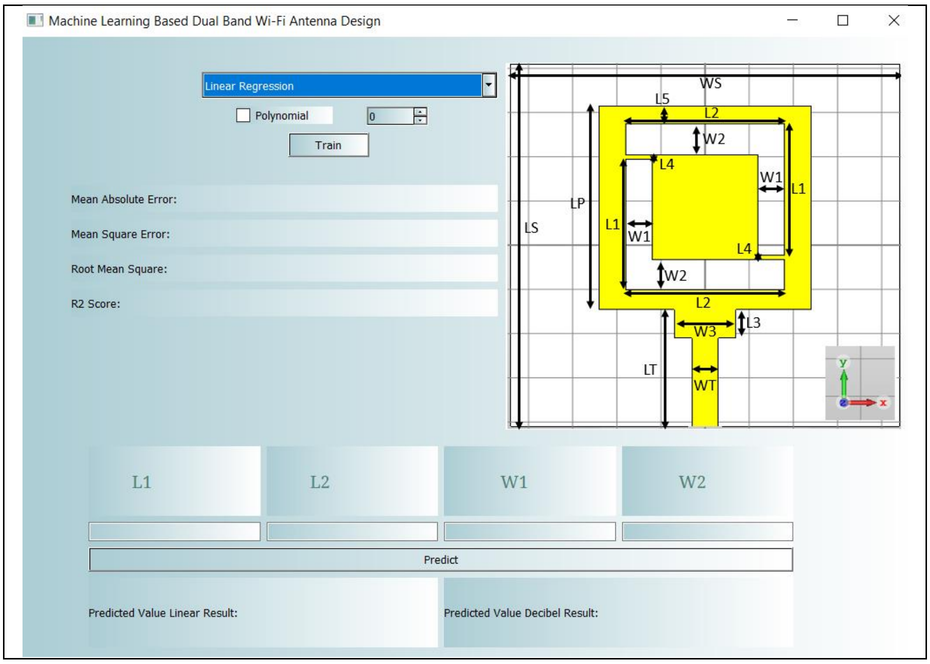

Figure 3. Graphical User Interface (GUI) Design with PyQt Designer

As a result, in this study, machine learning-assisted optimization has been achieved by above the steps mentioned. The steps followed in this study are shown in Figure 4. The prediction performance of the developed machine learning algorithms has been examined and the algorithm with the best prediction has been selected. The tables of these results are given in the next section. The design parameters used to obtain the electromagnetic characteristic of the proposed antenna and their rates of change are given in detail in Table 2.

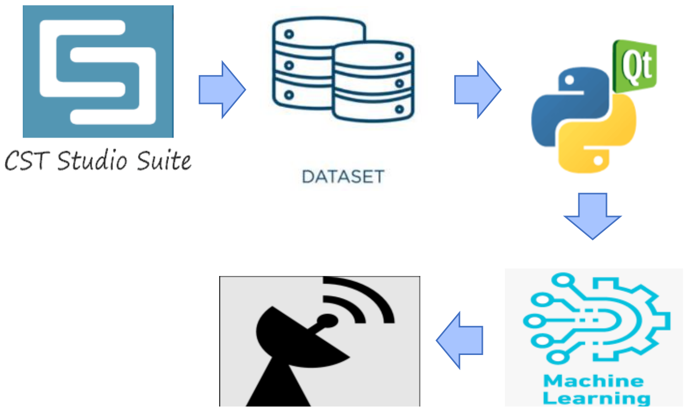

Figure 4. Work Follow-up Chart of Study

Table 2. Antenna Design Parameters for Dataset

Parameter	Change Rate (in mm)	Step Size (in mm)	Number of Samples
L1	[13.8 - 15.8]	0.5	5
L2	[11 - 15]	1	5
W1	[1 - 5]	1	5
W2	[2.5 - 4.5]	0.5	5
Total Data:		625	

4. Results

Linear regression, support vector regression, decision tree, and random forest algorithms have been developed in a python environment to provide antenna optimization in this project. The prediction results of these algorithms are given in the following tables. The results of the reflection coefficient of the proposed antenna have been taken in linear and decibels forms. Table 3 shows the prediction results for linear regression according to decibel and liner results of the reflection coefficient. Tables 4, 5, and 6 show the prediction results for support vector regression, decision tree, and random forest algorithms in the same order for the decibel and linear reflection coefficient.

Table 3. Results of Linear Regression Algorithm for

a) dB dataset

Mean Absolute Error	0.604
Mean Squared Error	0.670
Root Mean Squared Error	0.818
R Square Value	0.330

b) Linear dataset

Mean Absolute Error	0.545
Mean Squared Error	0.457
Root Mean Squared Error	0.676
R Square Value	0.543

Table 4. Results of SVR Algorithm for

a) dB dataset

Mean Absolute Error	0.373
Mean Squared Error	0.529
Root Mean Squared Error	0.727
R Square Value	0.471

b) Linear dataset

Mean Absolute Error	0.29
Mean Squared Error	0.199
Root Mean Squared Error	0.446
R Square Value	0.80

Table 5. Results of Decision Tree Algorithm for

a) dB dataset

Mean Absolute Error	0.170
Mean Squared Error	0.155
Root Mean Squared Error	0.394
R Square Value	0.845

b) Linear dataset

Mean Absolute Error	0.064
Mean Squared Error	0.005
Root Mean Squared Error	0.075
R Square Value	0.97

Table 6. Results of Random Forest Algorithm for

a) dB dataset

Mean Absolute Error	0.242
Mean Squared Error	0.197
Root Mean Squared Error	0.444
R Square Value	0.803

b) Linear dataset

Mean Absolute Error	0.099
Mean Squared Error	0.017
Root Mean Squared Error	0.131
R Square Value	0.983

The prediction results of the reflection coefficients (linear and dB forms) of the proposed antenna design are presented in this section. Linear (Figure 5), Support Vector (Figure 6), Decision Tree (Figure 7), and Random Forest (Figure 8) regression techniques have been implemented, respectively. Using 10 test data, prediction performance difference graphs of machine learning algorithms are presented in figures.

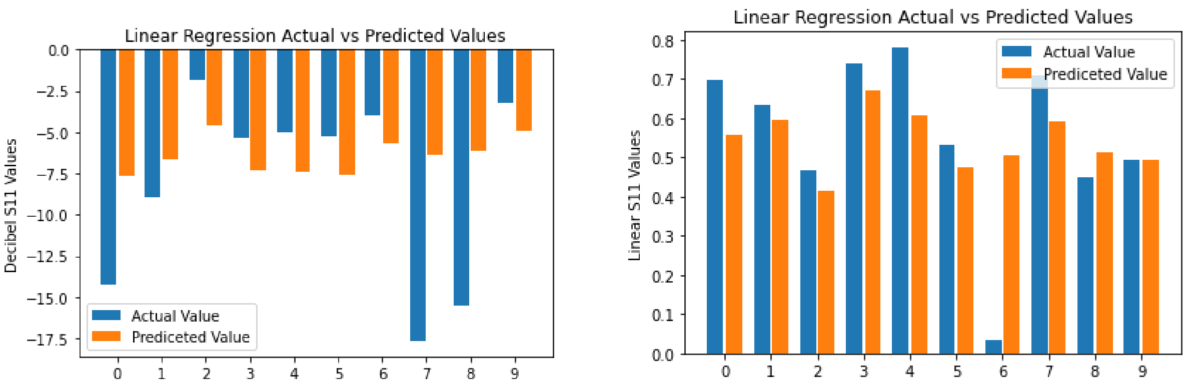

Figure 5. Actual / Predicted Values for dB and Linear Dataset in Linear Regression Algorithm

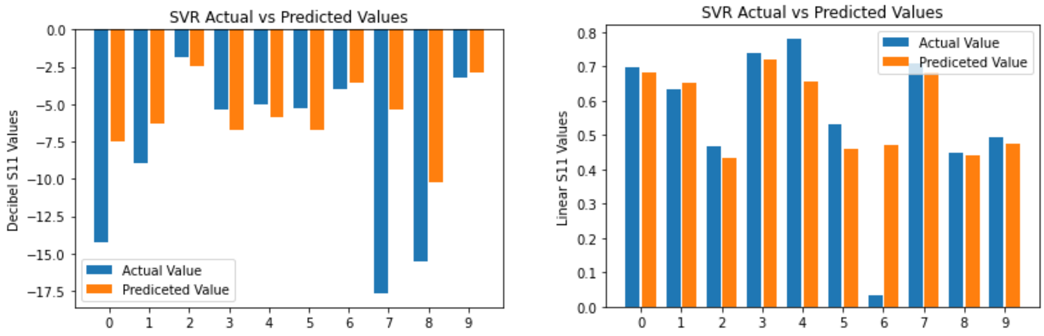

Figure 6. Actual / Predicted Values for dB and Linear Dataset in Support Vector Regression Algorithm

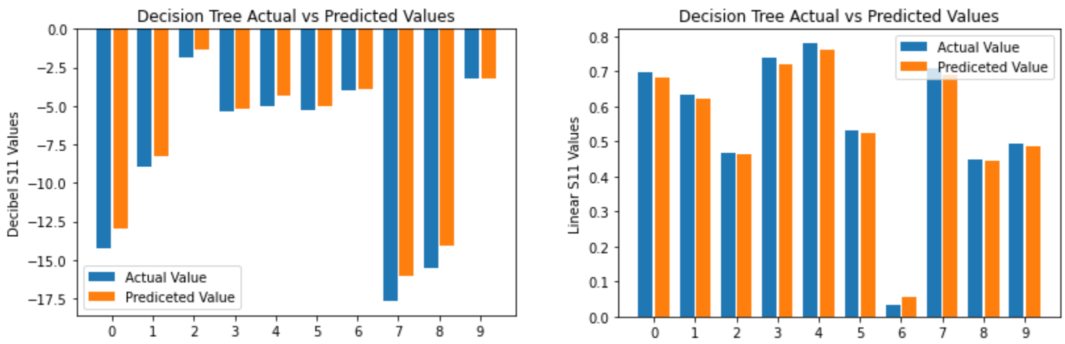

Figure 7. Actual / Predicted Values for dB and Linear Dataset in Decision Tree Algorithm

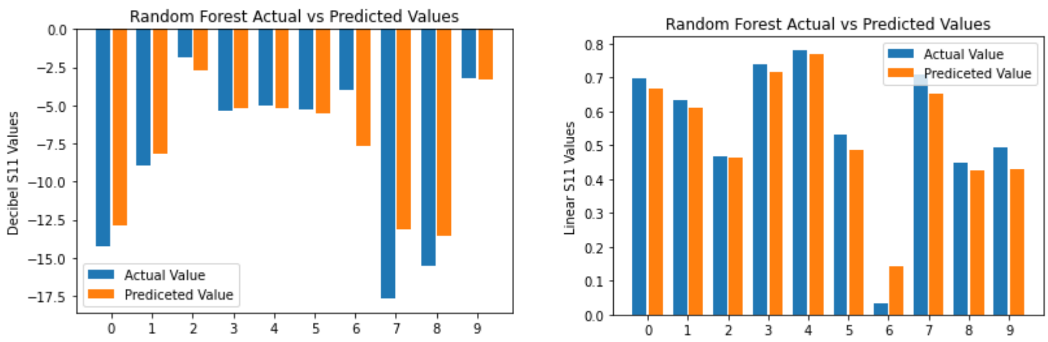

Figure 8. Actual / Predicted Values for dB and Linear Dataset in Random Forest Algorithm

5. Conclusion

In this study, firstly, a microstrip antenna design with a resonant frequency of 2.4 GHz has been realized that can be used in Wi-Fi applications. The proposed antenna design has been fed using the microstrip line feeding method. FR-4 has been used as the dielectric material and copper has been used as the radiating surface. The simulation stages have been carried out in the CST Studio Suite. Secondly, the electromagnetic characteristic of the antenna developed using CST is obtained. Therefore, by changing 4 different design parameters, a dataset consisting of 625 samples showing the change of antenna reflection coefficient has been obtained. The dataset has been divided into 0.2 test and 0.8 training. Thirdly, the Machine Learning algorithm, which is necessary for estimating the performance data of the antenna, has been developed in the Python environment with 4 different machine learning algorithms, Linear Regression, Support Vector Regression, Decision Tree, and Random Forest. The prediction results of these algorithms have been examined and the prediction algorithm that gives the best result has been selected. That algorithm is the Random Forest machine learning algorithm. As shown in table 6.b, random forest algorithm has highest R^2 value with 0.983. Also, it has lowest error values with MAE is 0.099, MSE is 0.017 and RMS is 0.131. The results have been examined by running the developed algorithm. It has been observed that the obtained results have an acceptable level of predictive performance. Also, it has been observed that the accuracy of the algorithm increases when the dataset recorded as linear is used in the prediction algorithm.

Antenna optimization will be achieved in quickly, using the obtained machine learning algorithm without the need for long-time simulation stages. Finally, an interface design has been performed using PyQt Designer. Thus, this graphical user interface design and prediction results of the antenna reflection coefficient can be performed using all the algorithms that have been developed.

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Declaration of Interest

The authors declare that there is no conflict of interest.

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Research Article

Machine Learning Based High Gain Wireless Antenna Design Operating at 5.2GHz Frequency

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Abstract

When it comes to 3G, 4G and the latest technology, 5G, the relevance of wireless communication is increasing day by day in a digitized and developing world. The increasing use of wireless communication highlights the need for wireless communication devices. The need for a premium version arises when the previous elements do not meet the requirements. Wi-Fi networks are one of the most common types of wireless communication. The most important component of the data flow in this system is the antenna. Several studies have been conducted in order to meet the requirements and make appropriate transfers. The planned antenna frequency is 5.2GHz. 5.2 GHz is the newest technology. With the integration of machine learning, predictive systems have been activated. There is planning to develop wideband antenna designs to facilitate wireless communications in this wide frequency range. The main goal of this article is to build a single antenna that can operate across multiple frequency ranges, rather than multiple antennas operating at big range frequencies. About 0.33 is reserved for prediction. Analysis was performed using 500 iterations of 3 parameters. This antenna design uses an FR-4 substrate with a dielectric coefficient of 4.3. Copper is used as a material for ground and patch components. 5.2GHz operating frequency, return loss 31.24dB, bandwidth range 4.9-5.38, gain 3.57dB.

Keywords: Antenna Design, WLAN, Wireless, Machine Learning, Microstrip

1. Introduction

Microwave components specialized to this technical sector have been introduced as improved alternative designs to conventional microwave components with the development of sophisticated communication systems for the Wireless Local Area Network (WLAN) [1-4]. Wi-Fi was created to provide high-speed wireless internet [5]. It was designed to enable wireless connectivity in small public spaces such as the home, workplace, and cafeteria. There have been attempts to expand the region and make it useable across a city. For even a few kilometers of coverage, however, hundreds of radio stations are required. As a result, the price of the process increases exponentially [6]. Machine learning research is divided into five categories. Different forms of learning include supervised learning, unsupervised learning, semi-supervised learning, reinforcement learning, and intensive learning [7]. The learning mechanism of the machine learning algorithm is divided into three parts. The three are the selection process, the error function, and the optimization procedure. There were seven different forms of regression utilized. Their projected and typical states were computed. Mean Absolute Error, Mean Squared Error, Root Mean Squared Error, and R Square Value are the computations [8-9].

Linear regression is used to find the optimal linear connection or hyperplane for a set of points. The Support Vector Machine is a supervised learning method for solving classification problems. Based on the feature and aim, the decision tree classification approach creates a model in the form of a tree structure with decision nodes and leaf nodes. The decision tree algorithm is produced by splitting the data set into smaller or even smaller pieces. The random forest method is another supervised classification technique. It can help with both regression and classification problems. KNN is one of the algorithms used in Supervised Learning for classification and regression. It is considered the most fundamental machine learning algorithm. Unlike other Supervised Learning algorithms, it does not require training. There appears to be a variety of machine learning approaches to pick from these days. The neural network is one of them. The Naive Bayes classifier is a probabilistic pattern recognition approach that may be used with a statement that appears to be fairly restricting at first glance.

Zhang et al. studied frequency values of 2.4, 5.2, and 60 GHz [10]. The gains are 1.9 dBi for 2.4 GHz, 2.4 dBi for 5.2 GHz, and 16 dBi for 60 GHz, respectively. Wang et al investigated frequency values of 2.4, 5.2, 5.8, and 60 GHz [11]. Its gains are 0 dBi for 2.4 GHz, 2.5 dBi for 5.2 GHz, 2.5 dBi for 5.8 GHz, and 6 dBi for 60 GHz, respectively. Sun et al. worked on frequency values of 2.4, 5.2, and 5.8 GHz [12]. The gains are 1.66 dBi for 2.4 GHz, 4.75 dBi for 5.2 GHz, and 5.1 dBi for 5.8 GHz, respectively. Deng et al. experimented on frequency values of 2.4, 3 and 3.5 GHz [13]. By the way, the gains for 2.4 GHz are 1 dBi, 2 dBi for 3 GHz, and 2.5 dBi for

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3.5 GHz. Ding et al. experimented on resonant frequencies of 2.4, 5.2, and 60 GHz [14]. Even by way, its 2.4 GHz gains are 3.97 dBi, 4.07 dBi for 5.2 GHz, and 12.29 dBi for 60 GHz.

The paper has been structured as follows. In section 2, a discussion will be made about the design of the designed antenna, its dimensions, feeding methods, and the preferers application for simulation. In section 3, simulation results of the design antenna are presents. In section 4, the general summary of the study and conclusion have been explained.

2. Material and Method

2.1 Design of Antenna

The Wi-Fi antenna's overall design is shown in Figure 1. Figure 1 depicts the size of the antenna.

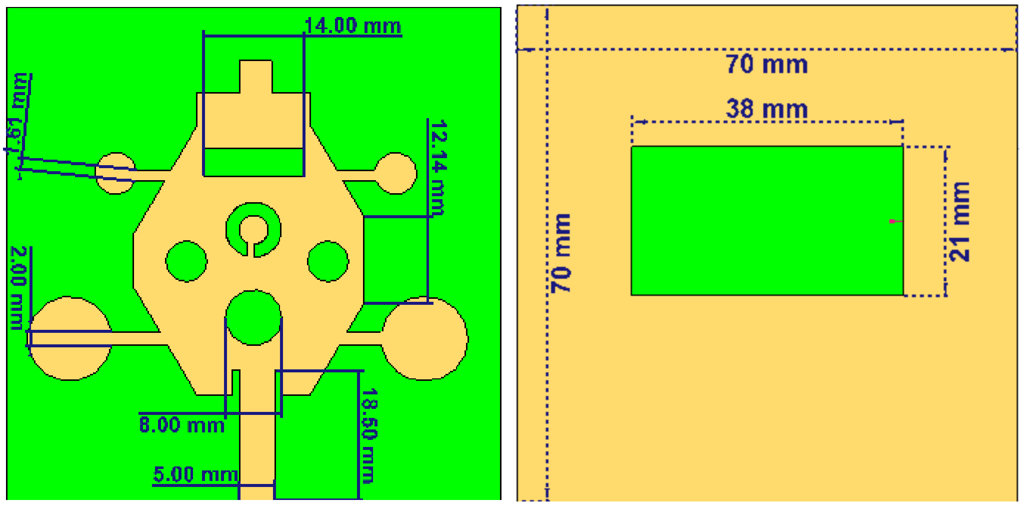


Figure 1*: Proposed Antenna Design*

There are three main components to consider while creating a microstrip antenna. Ground – Substrate – Patch When building an antenna, the ground layer, also known as the conducting layer, is created first. The antenna's ground material is copper, which has a thickness of 0.035mm. Electrical conductivity is required for this layer. The second layer is the substrate layer. The material FR4 is used for this layer. It is 1.6 mm thick and has a dielectric value of 4.3. FR4 material is used in most antenna designs. The second layer is the patch layer. The patch layer is where the antenna emits its radiation. This part has to be conductive. Copper was chosen since it was thought to be acceptable substrate for antenna because of it has low price and much effective. It measures 0.035mm thick.

3. Findings

Table 1 shows the various regression types, as well as their mean square errors and R2 values. Table 2 displays the outcomes of machine learning using Python. The optimal value has been determined to be random forest regression. The rectangular slot on the front is taken as the P1 variable. The rectangular slot on the back is taken as the P2 variable. The P3 variant is the circular slot on the front above the feed. The optimum values for P1 is 0, P2 is 1, and P3 is 1 are those that produce the most accurate antenna return loss value. It is also possible to forecast values outside of the database. Machine learning algorithms take information from a database and use them to produce predictions. The set is trained using 0.33 of the databases.

Polynomial linear regression, random forest regression, SVR and KNN, which are regression types in machine learning, are discussed. The Mean Square Error is calculated by dividing the sum of squares of the variances between each real value and the estimated value associated to that value by the sample size. Although perception has no intrinsic power, comparing many studied models can assist in the selection of the best model. It will always be a positive number. It shows that estimators perform better when the value is close to zero. The mean squared error (MSE) or mean squared deviation (MSD) of an estimator (of a process for estimating an unobserved variable) in statistics measures the average of the squared errors that is, the average squared difference between the estimated values and the actual value.

Table 1: *Regressions and MSE-R^2 Values*

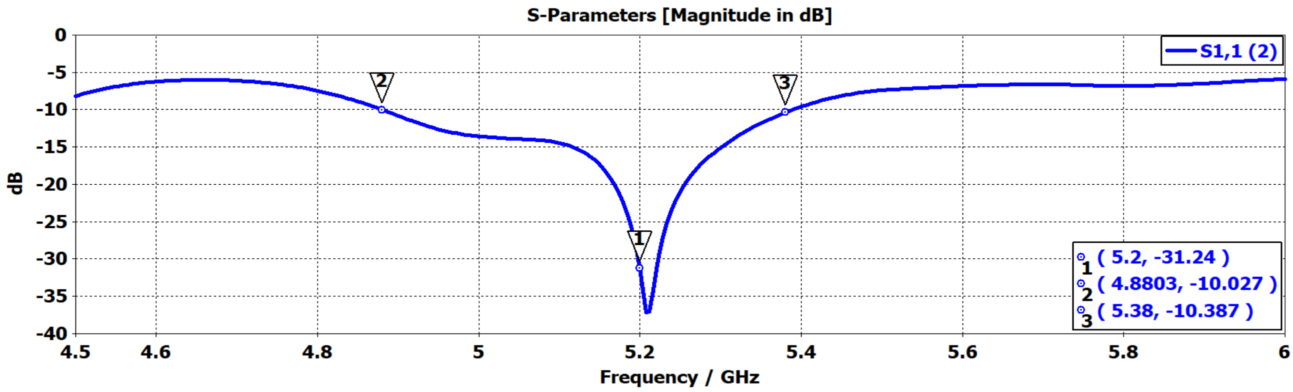
	Mean Square Error	R^2
POLYNOMIAL LINEAR REGRESSION	42.48890	0.47897
RANDOM FOREST REGRESSION	0.002552	0.99968
DECISION TREE REGRESSION	0.003157	0.99996
SVR	48.85987	0.40085
KNN	18.48277	0.77335

P1	0
P2	1
P3	1
POLYNOMIAL LINEAR REGRESSION	-29.486
DECISION TREE REGRESSION	-31.239
RANDOM FOREST REGRESSION	-31.123
SVR	-3.4319
KNN	-21.640

Table 2: *Machine Learning the Best Results*

When Table 1 was examined, it was observed that mean square error and r square values were for 5 different regressions. These regressions were observed as polynomial linear regression, random forest regression, decision tree regression, SVR and KNN. When Table 2 was examined, it was observed that the parameter values were for 5 different regressions. These regressions were observed as polynomial linear regression, random forest regression, decision tree regression, SVR and KNN.

Machine learning algorithms act as computers' minds, promoting learning and improve. More data means more processes are active, which causes the computer to learn and enhance its output. If the forecast does not turn out as expected, the algorithm is retrained until the desired outcome is achieved. This allows the machine learning system to self-train and provide the best possible response, which will increase in accuracy over time. The antenna's S parameter value is shown in Figure 3a. In the range of 4.89-5.38, a 31.24 dB return loss has been determined. Figure 3b depicts the radiation pattern of the proposed antenna with a gain of 0.798 dBi. Table 3 lists some of the machine learning-assisted antenna designs found in the literature, organized by antenna type, algorithm, and result section.



(a)

(b)

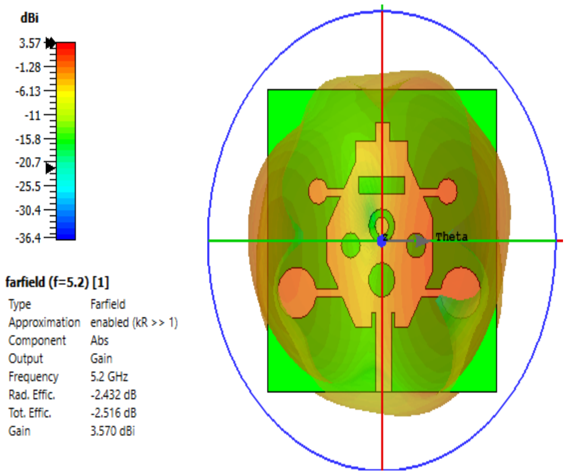


Figure 2*: a- S Parameter b- radiation pattern of proposed antenna*

Table 3*: Literature Review for machine learning assisted antenna designs*

REF NO	ANTENNA TYPE	ALGORITHM	COMPARED	RESULT
15	Reflectarrays	SVM	MoM&ANN	Design process is sped up while keeping high accuracy levels.
16	Rectangular Antenna	SVM	ANN	With a quicker convergence rate, the calculation efficiency improves.
17	E-Shaped Antenna	Linear	Conventional Simulations	The best outcomes discovered without the use of any simulations.
18	Microstrip Antenna	Gaussian ML	Differential Evolution	The speed of the design and optimization procedure by more than four times compared with differential evolution

4. Results

As a conclusion, this 5.2 GHz antenna is one cut above the rest of its industry competitive advantage in terms of both beauty and efficiency. It is more suitable than its rivals due to its effective working in the range of 4.8903-5.38 and low cost. The return loss is 31.24 dB, whereas the gain value is 3.57 dBi. Because this product is already pricey, a lower-cost antenna is constructed with a smaller surface area rather than a greater gain with this type of antenna. The antenna's s parameter graph is obtained after 448 iterations of three parameters. It has been observed that the antenna gives the most accurate results into 500 iterations for the parameter p1=0 p2=1 p3=1 when the antenna is inserted into machine learning. The best value, Decision Tree Regression, has been seen when it is inserted into machine learning. R^2 value is 0.99996. Mean Square Error value is 0.0031570. If the value of the s parameter, which is checked after making an estimation, is -31.2396. This was the closest predictive regression.

Declaration of Interest

I declare that there is no conflict of interest.

Acknowledgements

This study has been carried out using the laboratory facilities of İzmir Katip Celebi University Smart Factory Systems Application and Research Center (AFSUAM).

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