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Determination of Covid-19 Possible Cases by Using Deep Learning Techniques

Çinare OĞUZ*¹, Mete YAĞANOĞLU¹

Abstract

A large number of cases have been identified in the world with the emergence of COVID-19 and the rapid spread of the virus. Thousands of people have died due to COVID-19. This very spreading virus may result in serious consequences including pneumonia, kidney failure acute respiratory infection. It can even cause death in severe cases. Therefore, early diagnosis is vital. Due to the limited number of COVID-19 test kits, one of the first diagnostic techniques in suspected COVID-19 patients is to have Thorax Computed Tomography (CT) applied to individuals with suspected COVID-19 cases when it is not possible to administer these test kits. In this study, it was aimed to analyze the CT images automatically and to direct probable COVID-19 cases to PCR test quickly in order to make quick controls and ease the burden of healthcare workers. ResNet-50 and Alexnet deep learning techniques were used in the extraction of deep features. Their performance was measured using Support Vector Machines (SVM), Nearest neighbor algorithm (KNN), Linear Discrimination Analysis (LDA), Decision trees, Random forest (RF) and Naive Bayes methods as the methods of classification. The best results were obtained with ResNet-50 and SVM classification methods. The success rate was found as 95.18%.

Keywords: ResNet-50, Alexnet, Deep Learning, COVID-19, Classification

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1. INTRODUCTION

As stated by the World Health Organization (WHO), coronaviruses (CoV) are a one of the largest family at viruses are common in the community, such as the common cold that can cause more severe infections than mild infections. Diseases, caused by COVID-19 virus are an inflammatory diseases that caused by a new viruses. The disease causes respiratory distress with symptoms including colds, coughs, fever, and respiratory problems in more serious cases [1].

According to data of WHO, it is stated that the interest for personal protective equipment and respirators. The usage of masks increased by 100 times compared to normal levels and prices of related materials increased by about 20 times during the process following the spread of the virus [2]. In the process until February 11, 2020, the spread of the new virus on the world and the threats posed at the global level will increase [3].

Since there is no gold standard test that can provide 100% definitive diagnosis yet for the detection of COVID-19, it is attempted to reach the diagnosis by performing rapid antigen test, Polymerase Chain Reaction (PCR) test and by taking Computerized Tomography (CT) image.

COVID-19 case definition evaluation is performed for incoming patients. Within the scope of this evaluation, those who meet the COVID-19 case definition are included in the designated area. It is then examined and vital signs are checked.

Due to the limited number of COVID-19 test kits, these test kits are not administered to all suspected COVID-19 patients. For this reason, one of the first diagnostic techniques for individuals with suspected COVID-19 cases is Thorax Computed Tomography. As a result of positive findings on computed tomography, PCR test can be performed on the patient. Thus, efficient use of test kits is provided. CT equipment is available in almost all hospitals and it may be possible to use CT images to

investigate the COVID-19 cases without special test kits.

Since COVID-19 virus effects epithelial cells that can seal patient's airway, Computer Tomography can be used to examine the health of the patient's lungs. Doctors often use CT images to diagnose pneumonia, lung inflammation, abscesses and enlarged lymph nodes.

COVID-19 19 positive and negative lung CT images are shown in Figure 1. The figure shows a CT image of the lung of an individual infected with Covid 19 virus and a CT image of the lung of a healthy individual.

It is necessary to develop an automated diagnosis system to give medical professionals valuable advice so that the analysis of CT images does not require a radiologist and does not cause significant loss of time.

Common symptoms of this very spreading virus are respiratory symptoms, fever, cough and dyspnea. In more severe cases, it can result in severe consequences including pneumonia, kidney failure, acute respiratory infection. It can also cause death in serious cases. Therefore, early diagnosis is vital. In this article, it was aimed to analyze the CT images automatically and to direct probable COVID-19 cases to PCR test in order to ease the burden of healthcare workers.

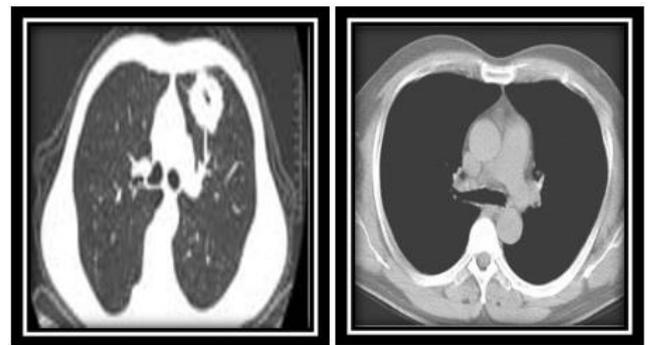


Figure 1. (Left) CT image of the lung of an individual infected with Covid 19 virus and (right) CT image of the lung of a healthy individual

Artificial intelligence (AI) is a tool used for estimation [4]. Deep learning, one of the sub-

branches of artificial intelligence, consists of steps involving the training process of many feed-forward neural networks. Deep learning architectures have been created with the advances in hardware and the increasing number of layers of the Artificial Neural Network and these have been involved in the solution of more complex problems. Deep learning is one of the last techniques applied in the field of diagnostic medicine [5], [6]. It can help us address issues that should be raised by the COVID-19 outbreak. Deep learning, a kind of artificial intelligence, works by recognizing designs in chronic educational knowledge. Using our dynamic knowledge to do the best speculation of what works and what can happen, we can practice from a situation and apply them to new conditions. The outbreak requires real-time analysis of high-dimensional and heterogeneous datasets. At this critical point, machine learning (ML) and deep learning have an important place for effective pandemic response.

The development of computer-assisted estimation and diagnostic tools has come to the fore with the development of medical image processing techniques[7].

Gu et al. [8] detected lung nodules with the model they developed with convolutional neural network and achieved a success rate of 79.67%.

Yadav et al. [9] used the SVM classification method for deep features obtained by InceptionV3 and VGG-16 models as a deep learning technique in the model they developed for the detection of pneumonia disease and achieved a success rate of 96.6%.

Talo [10] proposed an automatic recognition system for the diagnosis of pneumonia disease. ResNet-152 convolutional neural network was privatized a recognition success of 97.4% was achieved in the detection of pneumonia disease without any pretreatment or manual feature extraction on radiography images.

Couhan et al. [11] achieved a success rate of 96.39% by performing a transfer learning with normal, virus pneumonia and bacterial

pneumonia images for the diagnosis of pneumonia disease.

Abiyev et al. [12] achieved a success rate of 89.57% in diagnosing pneumonia disease by applying back propagation neural network and competitive neural network models using pneumonia and normal chest x-ray images.

Araujo et al. [13] classified the images at the patient level with a model similar to AlexNet for classification of cancer images. In this study, average accuracy of 90% and 85.6% with maximum fusion method was reported using different fusion techniques.

Pathak et al. [14] used a deep transfer learning technique to classify COVID-19 infected patients and achieved a success rate of 93.0189%.

Toğaçar et al. [15] processed the feature sets obtained with deep learning techniques by using Social Mimic optimization method and COVID 19, pneumonia and normal x-ray images and classified them with SVM in the model developed for the detection of COVID 19. Its success rate was 99.27%.

Ardakani et al. [16] evaluated performances using 10 well-known convolutional nerves to separate COVID-19 infection from non-COVID-19 groups. They achieved the best performance among all neural networks with ResNet 101 and Xception.

Sethy and Behara [17] did statistical analysis to choose the best classification model. They recorded this classification model as statistically superior compared to other ResNet-50 models. They obtained the proposed classification model for the detection of COVID-19 with an accuracy of 95.38%.

Xu et al. [18] divided the CT images of COVID-19 into three classes. The data set consisted of 618 images. They classified the images with a 3D deep learning model and achieved an overall classification accuracy of 87.6%.

2. METHODOLOGY

Deep learning is a sub-branch of machine learning related to algorithms inspired by the brain structure and functions. Deep learning models facilitate the detection of various diseases through images obtained using medical imaging techniques such as MRI and CT[19].

Basically, ML methods apply techniques such as various preprocesses, size reduction and feature selection to the untreated images, then manually extract features from the images obtained, or use the features extracted by other machine learning models. However, deep learning techniques perform automatic feature extraction without any preprocessing of images[20].

Therefore, we aim to determine whether patients are possible cases with CT images taken from suspicious COVID-19 patients by using deep learning models in the study to be conducted.

2.1. Dataset

Lung CT images used in this study were provided by the open source Kaggle[30] data set. The dataset used was divided into 1697 CT images as COVID-19 negative and 379 CT images as COVID-19 positive. In the study, 20% of 2076 CT images were used for testing.

2.2. Deep Learning Model

2.2.1 Alexnet

The winning of the alexnet model developed by Alex Krizhevskyin in the ImageNet Large Scale Visual Recognition Challenge 2012 (ILSVRC-2012) competition has led to an increased interest in deep learning. The classification has increased the accuracy rate from 74.3% to 83.6%.

Alexnet is the first model to run on a parallel dual GPU. Thus, the model is trained faster and memory problems are prevented.

It is a neural network containing 650000 neurons with 60 million parameters. It has a total of eight

learned layers, five convolutional and three fully connected [25]. The main purpose of the convolutional layer is to extract features and maximum pooling performs feature matching [26].

The input size of Alexnet is $227*227*3$ pixel. Normalization takes place after the first and second convolutional layer. Maximum pooling is applied both after normalization and after the fifth convolutional layer. RELU is used as the activation function. RELU is applied after each convolutional layer and to the output of the fully connected layer. It provides to reduce the training time. Each of the fully connected layers contains 4096 neurons. Dropout is applied in the first two fully linked layers to prevent the model from memorizing samples in training data [25].

The architecture of the Alexnet model is shown in figure 2.

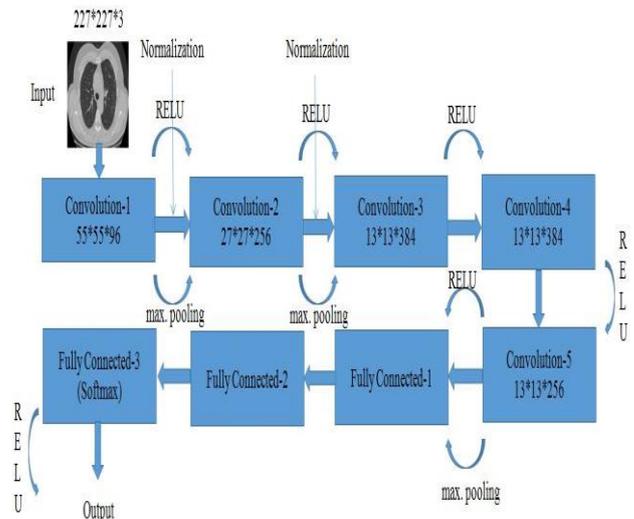


Figure 2. Architecture of Alexnet [25]

2.2.2 Resnet-50

Resnet-50 is a 50-layer network over the ImageNet dataset. Resnet-50 is an improved version of the Convolutional Neural Network (CNN). The Resnet model aims to solve the performance degradation problem of CNN

networks. As the depth of the network increases, loss of information occurs during parameter updates. To solve this problem, ResNet adds extra links between layers that connect the intermediate layers. Instead of creating a new network, using a trained models are more desirable [10].

Resnet-50 neural network consists of input, convolution, activation, pooling, normalization, fully connected, RELU, Softmax and classification layers as shown in Figure 3.

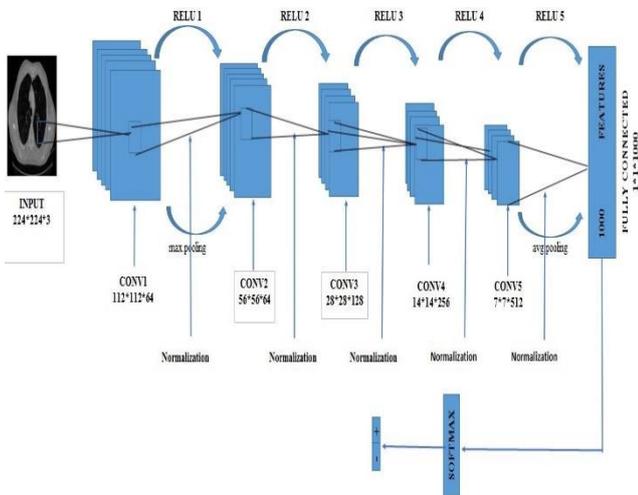


Figure 3. Architecture of Resnet-50[28]

The data is read in the input layer. The input size of Resnet is 224*224*3 pixel. In the convolution layers, activations from the previous layers are processed with various filters and the feature map is drawn for each filter. The convolution layer is the main building block of a CNN. The convolution layer does most of the computational dense elevation. Feature maps obtained from convolution layers are transmitted to the non-linear activation function. In addition, scaling is done on the image. To stabilize the training of the network in the normalization layer, standardization is performed based on the input values in the neuron. The training of the network takes place faster thanks to this process[29].

The layer that follows the convolution layer and processes the output of neurons to nonlinear processing forms the activation layer. Nonlinear features are added to the network with the help

of activation functions. The RELU activation function, which brings nonlinear features to the neural network, is often used in intermediate layers. After the activation process, each feature map can be reduced in size in the pool layer. Thus, the amount of calculation is reduced by reducing the number of parameters in the network. Average pooling and maximum pooling are the most common methods. The model to be used is available in both. No learning process takes place in this layer[29].

The data obtained from the previous layers in the fully connected layer is converted into a one-dimensional matrix in this layer. The Softmax activation function provides a categorical probability distribution using the neural network's output. The classification layer is the last layer of the network used after the Softmax layer. The output value of this layer is equal to the number of classes. In this study, there are two output values as COVID-19 positive and negative.

The block diagram of this study is shown in Figure 4. Deep feature extraction is based on the extraction of features from the pre-trained Resnet-50 neural network. Deep features are removed from the fully connected layer and the feature vector is obtained.

Deep features obtained from Resnet-50 and Alexnet networks are used by various classifiers (Knn, SVM, Naive Bayes, Decision Trees, RF and Discriminant Analysis) and the performance of all classification methods is measured.

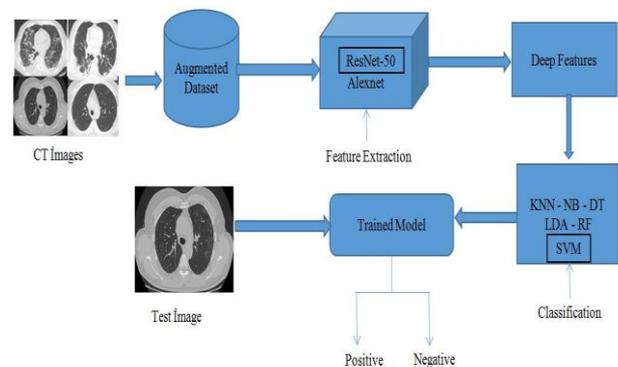


Figure 4. Block diagram

2.3. Classification Methods

2.3.1. K-Nearest Neighbors Algorithm (Knn)

Knn method is a widely used ML method to classify the test dataset according to the features obtained from the training set [22].

Cross Validation is a method used to estimate the ability of machine learning models. It is widely used in machine learning to compare and select a model for a given predictive modeling problem. The K value was determined using cross validation. The best k value was determined as 5.

The distance function is calculated between the samples in the training set and the test data. Euclidean method is used to calculate the distance between the data. Then, the distances obtained are listed and the closest k samples to the test data are selected in the training set. Among these examples, the most common class is considered to be the class of test data.

2.3.2. Support Vector Machine (SVM)

The SVM method is a statistical learning algorithm introduced by Vapnik, which has been widely used recently. Two hyperplanes are calculated: negative hyperplanes and positive hyperplanes belonging to the two classes obtained with the training dataset. An appropriate hyper plane is obtained which can make the best distinction between the two classes that are equidistant from these two hyperplanes. Support vectors closest to this hyperplane are called support vectors. The test data is then classified by the plane obtained [23]. In Figure 5, support vectors and separation plane are shown in SVM.

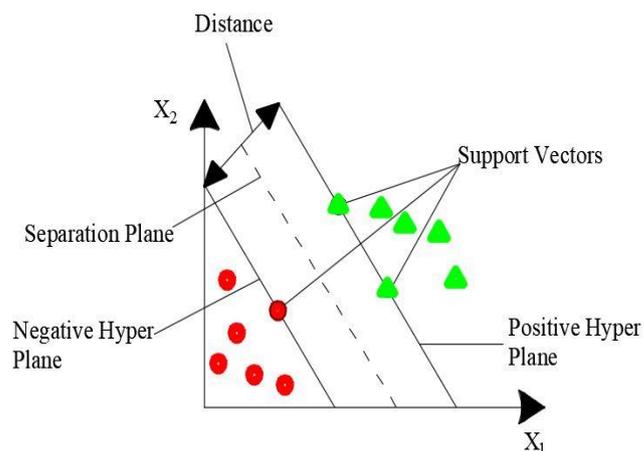


Figure 5. Support vectors and separation plane [27]

2.3.3. Decision Trees

The method of decision trees (DT) is an easy and common method unlike artificial neural networks in terms of classification [22]. The algorithm of decision trees takes place in two stages. First, a node of the tree is created using the features obtained from the training dataset, and then the process of dividing this data into two new nodes based on that feature takes place. The leaves of the tree are formed from these nodes. The division continues until each branch is labeled with only one classification. In the second stage, unnecessary branches of the tree are cut [22], [24]. Starting from the root node at the top of the Decision tree with test data, all possible outputs of the branch and the decision nodes are tested.

2.3.4. Random Forest (RF)

Random forest is a machine learning method that includes many decision trees, developed by Breiman [33] for regression and classification problems.

To train the classifier, multiple bootstrap training data sets are created from the original training data set with displacement, and a tree is generated for each bootstrap training data set. In while the original training set for currently tree is changed and sampled, approximately one third of the cases are excluded from the sample. This out-of-bag data is used to obtain an estimate of the classification error as the trees are insert to the forest. Incorrectly classified samples are

increased in weight to be more important in the next iteration [34].

2.3.5. Linear Discriminant Analysis (LDA)

The method of linear discriminant analysis is one of the widely used ML techniques based on statistical methods. This method aims to make the maximum in-group distance minimum[26]. It produces discriminant functions for all classes to separate classes. The discriminant function is given in equation 1.

$$f_i = \mu_i C^{-1} x_k^T - \frac{1}{2} \mu_i C^{-1} \mu_i^T + \ln\left(\frac{n_i}{N}\right) \quad (1)$$

N represents the total number of data. While n_i is the number of data belonging to class i , μ_i refers to the average value of class i . C is the covariance matrix belonging to class i .

The test data is considered to belong to that class, whichever of the discriminant functions obtained for each class gives the highest results.

2.3.6. Naive Bayes

Naive Bayes (NB) method is a simple statistical approach classification method based on independent assumption. Basically, the Naive Bayes classifier accepts the fact that a class has a particular feature is irrelevant to having any other features. The advantage of the Naive Bayes method is that it requires few training data for classification.

In the Naive Bayes classification, a certain amount of taught data is presented to the system. The probability processes are applied on the taught data, the test data is evaluated according to the obtained probability values and it is tried to determine which class the test data belongs to.

In the NB method, $X = x_1, x_2, \dots, x_n$ is an example of data whose class is unknown. Let C_1, C_2, \dots, C_m be the possible class values. The probabilities of the features of X by classes are calculated as in equation 2.

$$P(X|C_i) = \prod_{k=1}^n P(x_k | C_i) \quad (2)$$

The probability of X belonging to each class is calculated in equation 3. In this case, it is decided which class X belongs to according to the biggest result.

$$P(C_i|X) = \frac{P(X|C_i)P(C_i)}{P(X)} \quad (3)$$

3. PERFORMANCE ANALYSIS

The detection of COVID-19 probable case was performed on MATLAB R2020a on a computer with Intel(R) Core (TM) i3-3220 CPU @ 3.30 GHZ. 4 GB RAM using ResNet-50 and Alexnet architecture. The dataset used in the reported experimental results consists of 2076 CT images. Of this dataset, 80% was used for training and 20% for testing.

The confusion matrix is the summary of the educated network and it shows the performance of the network. A general confusion matrix is shown in Table 1 [31].

Table 1.
Confusion matrix

	Covid-19 Positive	Covid-19 Negative
Covid-19 Positive	TP	FP
Covid-19 Negative	FN	TN

TP: The image of COVID-19 is estimated to be positive and this image is positive.

TN: The image of COVID-19 is estimated to be negative and this image is negative.

FP: The image of COVID-19 is estimated to be negative, but this image is positive.

FN: The image of COVID-19 is estimated to be positive, but this image is negative.

Accuracy, Sensitivity and Specificity are calculated by equation 4,5,6 [32].

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} \quad (4)$$

$$\text{Sensitivity} = \frac{TP}{TP+FN} \quad (5)$$

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (6)$$

Resnet-50 and Alexnet deep learning techniques were used in the extraction of deep features. As classification methods, their performance was measured using SVM, KNN, LDA, Decision trees, RF and Naive Bayes methods. In Figure 6, the success rate of classification methods is given by using the deep features obtained with Resnet-50. As can be seen in Table 3, the best results were obtained with Resnet-50 and SVM classification methods. The confusion matrix obtained by using Resnet-50 and SVM methods together is given in Table 2. The success rate was recorded as 95.18%.

Table 2.
Comprehensive confusion matrix of Resnet-50 SVM methods

	Covid-19 Positive	Covid-19 Negative
Covid-19 Positive	67	9
Covid-19 Negative	11	328

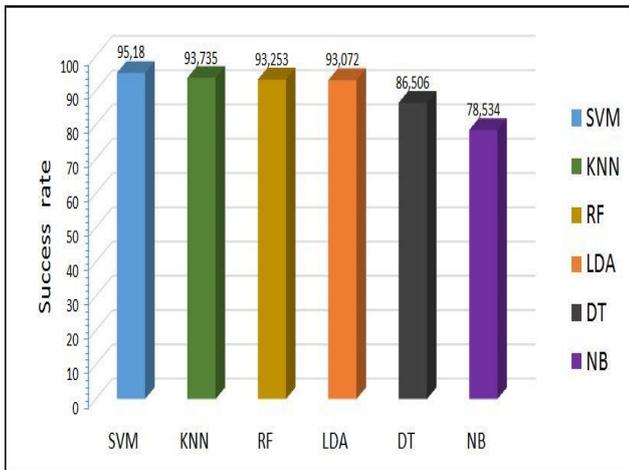


Figure 6. Success rate of classification methods with Resnet-50

Table 3.
Experimental results

		Accuracy (%)	Sensitivity (%)	Sensitivity (%)
ALEXNET	NB	75.904	72.861	89.473
	SVM	92.289	88.158	93.215
	KNN	91.566	84.211	93.215
	LDA	91.265	67.213	96.678
	DT	86.747	76.316	89.086
	RF	94.458	84.416	96.746

RESNET50	NB	78.534	75	79.351
	SVM	95.180	88.158	96.755
	KNN	93.735	85.526	95.575
	LDA	93.072	80	95.955
	DT	85.506	57.895	92.92
	RF	93.253	81.579	95.870

4. CONCLUSION

In this study, the performances of various classification methods were evaluated by using deep learning techniques for possible COVID-19 case detection from lung CT images. From the experimental results obtained, we see that the specificity values are higher than the sensitivity values in each classification method. Because more COVID-19 negative images in the dataset enabled the model to learn better the COVID-19 negative class type. It is planned to increase the success rate by increasing the number of insufficient COVID-19 positive images in the future. In addition, artificial neural network method can be considered as a classification method.

Intelligent algorithms focused on ML can provide effective responses and enhancements to the COVID-19 pandemic, while contributing to the development of various models, widely used in clinics around the world. This can help predict COVID-19 health outcomes in a variety of geographic and health systems environments. ML will help reduce diagnostic errors and unnecessary use of diagnostic tools through the development of rational algorithms. The model developed in this study can be used as an assistant decision support system by preventing unnecessary tests for COVID-19 disease. The purpose of the developed system is not to replace a specialist, but only to support the decision to be made in the light of the information obtained from the experts working on the subject during the diagnostic phase.

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THE DECLARATION OF CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

THE DECLARATION OF ETHICS COMMITTEE APPROVAL

This study does not require ethics committee approval or any special permission.

THE DECLARATION OF RESEARCH AND PUBLICATION ETHICS

In the writing process of this study, international scientific, ethical and citation rules were followed, and no falsification was made on the collected data. Sakarya University Journal of Science and its editorial board have no responsibility for all ethical violations. All responsibility belongs to the responsible author and this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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