Identifying Pneumonia in SARS-CoV-2 Disease from Images using Deep Learning

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***Abstract*— Deep learning methods are commonly used in various applications now a days. It has also shown its effectiveness in the field of medicine and is actively used as an auxiliary technology. Although the COVID-19 epidemic is an unprepared process in the world, it has been one of the times when alternatives were most needed for diagnosis and treatment. Considering the cost of tests such as PCR in the diagnosis of the COVID-19 epidemic, it has become a need to create economical alternatives. In this context, the main objective of this study was to diagnose and distinguish between COVID-19 and pneumonia cases with CNN-based multiple models using images of chest X-rays. Specifically, three different CNN-based models were used, namely: InceptionV3, ResNet50, and InceptionResNetV2. Moreover, different optimizers were also investigated to identify the best performing one. The models were trained on chest X-ray of 100 patients with COVID-19 and pneumonia. The experimental results showed that the SGD optimizer with the highest accuracy came to the fore with a value of 98.8%.**

***Keywords*— pneumonia, COVID-19, SARS-CoV-2, Deep Learning**

I. INTRODUCTION

The epidemic caused by the SARS-CoV-2 virus and commonly known as COVID-19 was first seen in Wuhan, China, and affected the whole world. The COVID-19 epidemic declared as a pandemic by the World Health Organization (WHO), has affected 82,579,768 people worldwide and caused the deaths of 1,818,849 people today (03.01.2020) [1, 2].

The mortality rate is very high as there is no specific drug or treatment method is available to treat the disease. Therefore, it continues to be an epidemic that people are very worried about around the world [3].

The similarity between pneumonia disease and COVID-19 epidemic disease makes it inevitable to confuse COVID-19 with pneumonia disease in this process. It can be stated that technology can be a helpful factor in distinguishing two diseases since the number of experts trained in this field is insufficient [4].

When pneumonia disease, also known as pneumonia, is not diagnosed early and correctly, it can lead to the death of patients, although not as high as the high mortality rate of COVID-19 disease today [5]. Pneumonia can be expressed as a disease that causes severe respiratory distress by affecting the lungs with the effect of viruses and bacteria [5]. Pneumonia causes damage to the person by making breathing difficult as a result of the damage to the air sacs that must be active in the lungs during breathing. This disease usually affects patients with weakened immune systems and can cause death [6].

COVID-19 epidemic disease is caused by the SARS-CoV-2 virus and in humans; It presents with symptoms of coughing, high fever, sore throat, and difficulty breathing. Along with these symptoms, different symptoms such as taste difficulty and muscle pain can be seen. The virus transmitted from person to person through channels such as coughing shows its effects during the 14-day incubation period [7].

In this study, it was aimed to compare the results with other studies in the literature by applying the Convolutional Neural Network (CNN), which is a deep learning model for the determination of X-rays of COVID-19 and pneumonia patients using data sets consisting of chest X-rays. The results obtained within the scope of the research are presented in tables and graphics. The results obtained within the scope of the research; It has been compared with other studies in the literature within the scope of values such as accuracy, loss, and sensitivity.

II. LITERATURE REVİEW

As the importance and effect of pneumonia disease after the COVID-19 epidemic is repeated more frequently, understanding the difference between these diseases directly affects the treatment processes. In this context, the number of studies in which models are developed to distinguish COVID-19 and pneumonia from chest X-rays using deep learning techniques is increasing. Details of some of the studies in the literature are as follows:

Within the scope of the study, it is seen that the model created with deep learning techniques using two open data sets of COVID-19, pneumonia, and normal patients was tested and the results were shared. In the study, a model created by the combination of Xception and ResNet50V2 networks is proposed. The average accuracy of the proposed model in detecting COVID-19 cases was 99.50%, and the overall mean accuracy for all classes was 91.4% [10].

In a different study, it was provided to train with datasets on COVID-19 and normal (healthy) human chest X-rays using CNN models. Within the scope of the study, CNN models ResNet18, ResNet50, ResNet101, VGG16, and VGG19 were used. During the experimental process of the study, measurements of classification accuracy were made using a data set containing 180 COVID-19 and 200 normal (healthy) chest X-rays. Within the scope of the created model, the highest result obtained as a result of the deep features extracted from the ResNet50 model and SVM classifier was observed as an accuracy score of 94.7%. It has been emphasized that CNN models and SVM classifiers are highly efficient in the detection of COVID-19 compared to local tissue descriptors [11].

By using chest X-rays and tomography films, the researchers used CNN, which is one of the deep learning models, in the process of identifying COVID-19 by training the data. Within the scope of the research, a new model named CoroDet based on CNN was proposed. In the proposed model 2 (COVID-19, Normal), 3 (COVID-19, Normal, Non-COVID-19 Pneumonia) and 4 (COVID-19, Normal, non-COVID-19 viral pneumonia and non-COVID-19 bacterial pneumonia) classifier is used . The accuracy values of the proposed model are expressed as 99.1% in a 2-class classifier, 94.2% in a triple classifier, and 91.2% in a 4-class classifier. As a result of the research, it was stated that the CoroDet model is superior to existing technologies and can be helpful in decision-making in clinical processes [12].

One of the healthiest models recommended for diagnosis during the COVID-19 pandemic is PCR tests. However, in the study, which stated that alternatives could be created in diagnostic processes with technological different methods due to the limited number of test kits, [13], it was aimed to investigate a new model to be created with a pre-trained multiple CNN model for COVID-19 chest X-ray films. Open data sets were used in the research. Within the scope of the research, in the first data set consisting of 453 COVID-19 chest X-rays and 497 non-COVID chest X-rays, an accuracy of 0.963 AUC and 91.16% was achieved with the model created. In addition, in the second data set consisting of 71 COVID-19 chest X-ray images and 7 non-COVID chest X-rays, an accuracy of 0.911 AUC and 97.44% was achieved with the model created. As a result of the research, it was stated that pre-trained multiple CNNs were more effective than single CNN in the diagnosis of COVID-19.

F In a different study, a model using chest X-rays was proposed because of the higher cost of obtaining tomography images. In addition, the fact that the images that are easier to access in hospitals are chest X-rays is also presented as a factor. Within the scope of the research, a new model created from multiple CNN models was proposed and compared with different CNN models. COVID-19 is used as the classifier, and a 3-classifier is used as the other. As a result of the research, accuracy of 99.5246% was obtained. It has been stated that the proposed model gives more effective results compared to other CNN models (VGGNet, ResNet50, Alexnet, Googlenet InceptionnetV3, etc.) [7].

The effect of a new CNN model-based model was investigated using data sets consisting of images of chest X-rays. The name of the new model proposed within the scope of the research was determined as CovXNet and normal, pneumonia (viral and bacterial), and COVID-19 chest x-ray images obtained from open data sets were used. For the COVID / Normal classifier the accuracy was 97.4%, for the COVID / Viral pneumonia classifier 96.9%, for the COVID / Bacterial pneumonia classifier 94.7%, and for multi-class COVID / normal / Viral / Bacterial pneumonia% An accuracy of 90.2 has been achieved. It can be stated that the model proposed as a result of the research can serve as a diagnostic tool in the current situation of the COVID-19 pandemic [4].

In the study where a new model based on the CNN model was proposed, a data set consisting of images of chest X-rays was used. Within the scope of the model, images of chest X-rays were trained with a 12-class structure and it was stated that an accuracy value of 86% was reached as a result of testing the model [14].

In a different study [15], it was aimed to identify tuberculosis patients with a CNN-based model using images of chest X-rays. The accuracy value obtained as a result of testing the developed model was specified as 85.68%.

Information on other studies conducted is summarized in Table I. The results presented in these studies indicate that deep learning-based techniques are very effective for identification of COVID-19 positive cases.

TABLE I. INFORMATION ON OTHER STUDIES IN THE LITERATURE

No	Name of Study	Purpose of Study	Result
1	Covid-net: A tailored deep convolutional neural network design for detection of covid-19 cases from chest x-ray images [16]	It is aimed to identify the COVID-19 patient with the CNN-based model, using images of chest X-rays.	As a result of the research, the model using the data set using the images of 13,975 chest X-rays reached 98.9% accuracy.
2	Covidx-net: A framework of deep learning classifiers to diagnose covid-19 in x-ray images [17]	Automatic diagnosis of COVID-19 disease is aimed with a newly developed model named COVIDX-Net.	Images of 50 normal and 25 COVID-19 patients were used within the scope of the study, and the accuracy rate of the proposed model named COVIDX-Net was expressed as 91%.
3	Deep learning based detection and analysis of COVID-19 on chest X-ray images [18]	Images of chest X-rays of healthy and COVID-19 patients were processed and analyzed comparatively using CNN models.	As a result of the research, in the study in which Inception V3, Xception and ResNeXt models were used, 5467 of the open data sets were used for training models and 965 for verification. When the comparison results are examined, the Xception model has achieved 97.97% results compared to other models.
4	Cascaded deep learning classifiers for computer-aided diagnosis of COVID-19 and pneumonia diseases in X-ray scans [19]	Within the scope of the study, it is aimed to train the data set consisting of images of COVID-19, non-COVID-19 viral pneumonia and non-COVID-19 bacterial pneumonia chest X-ray films with VGG16, ResNet50V2, and Dense Neural Network (DenseNet169) models.	Within the scope of the study, the data set consisting of images of COVID-19, non-COVID-19 viral pneumonia and non-COVID-19 bacterial pneumonia chest x-ray films were trained with VGG16, ResNet50V2, and Dense Neural Network (DenseNet169) models, and as a result, 99.9% accuracy was achieved.

III. MATERIAL AND METHODS

The sample architecture of the proposed method used in this study is shown in Fig. 2. Although the model to be used in the research is the CNN model, the images were initially resized as 224 × 224 pixels in order to be suitable for this model.

Brief information about the CNN model as the deep learning model suggested in the study is as follows:

Deep learning models are used quite effectively in processes such as examining medical data, classification, and segmentation. As a result of processing these data with deep learning models, it can be used to facilitate the diagnosis of epidemic diseases such as pneumonia and some types of cancer as well as epidemic diseases such as COVID-19 [20, 21].

The Convolutional Neural Network (CNN) model can be defined as a class of deep neural networks used in image recognition problems [22].

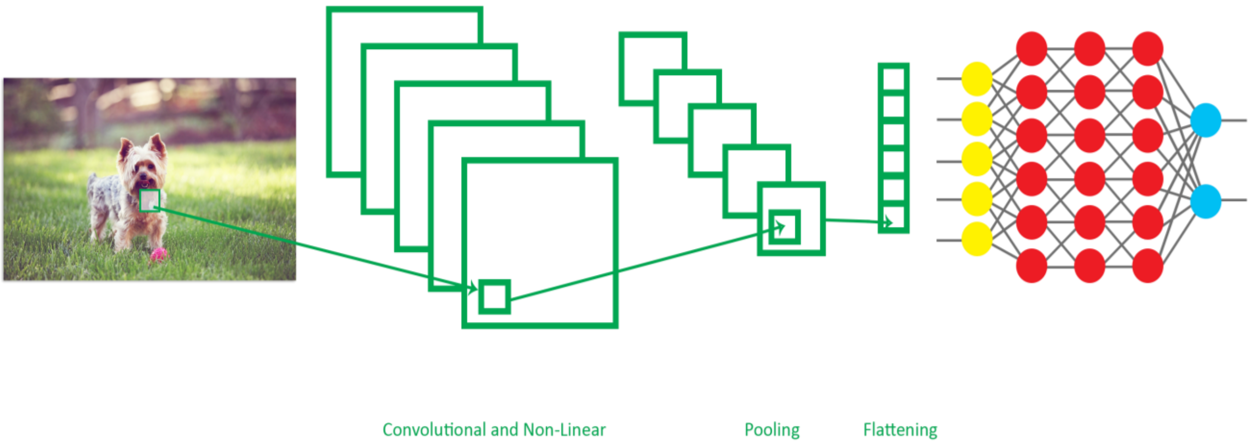

Fig. 2. CNN Model Layers Diagram [23]

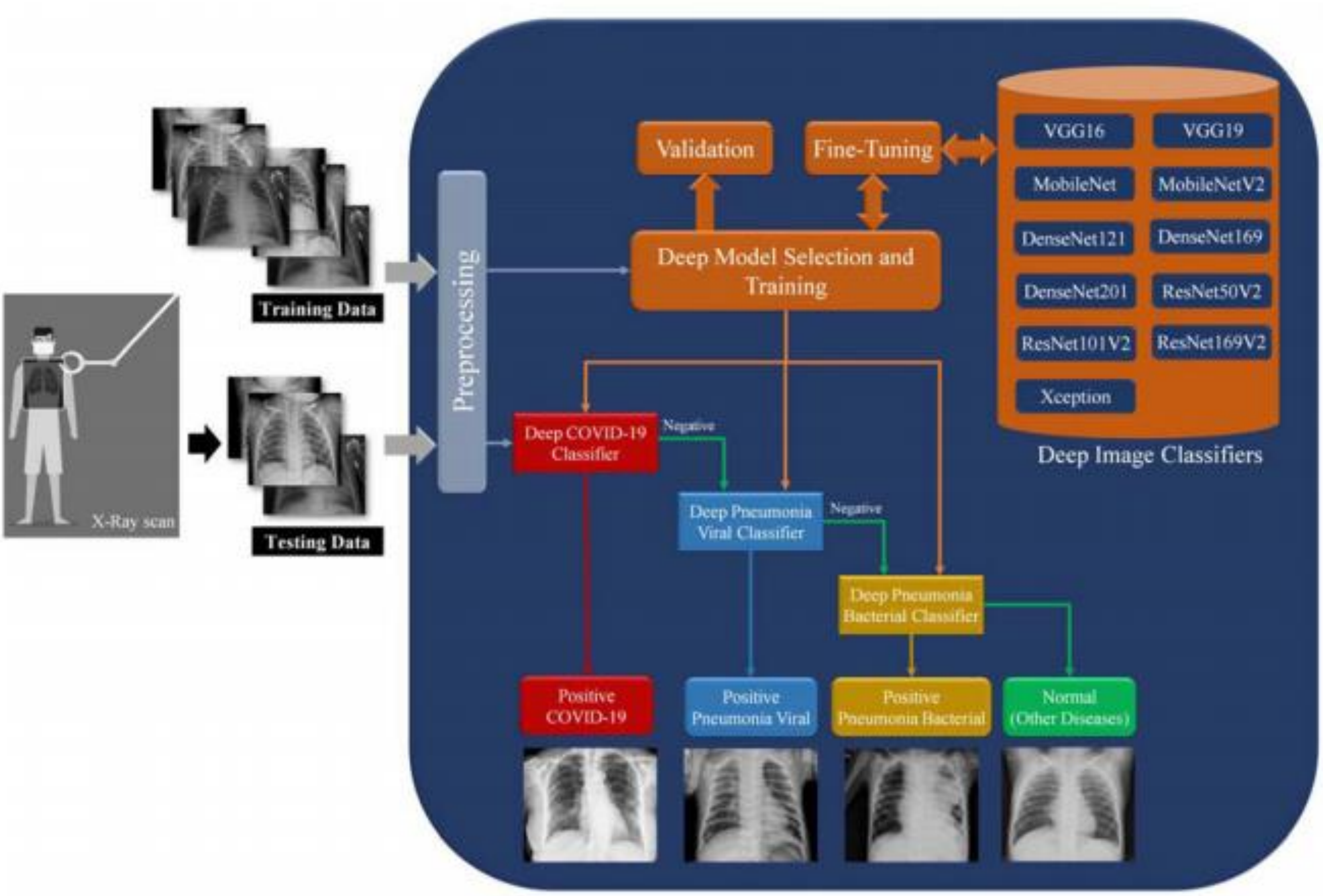

Figure 3. Work Flow of the CNN-Based Proposed Model within the Scope of Identifying COVID-19 and Pneumonia Patients Using Chest X-rays [19]

The working principle of the CNN model can be expressed as converting the images taken as input into a format that can be processed by the computer. Accordingly, the images are converted into matrix format and they try to determine which label the new images belong to by learning the effects on the label according to the image differences, namely the matrix changes. The learning process of this model consists of different layers. These layers are named as a convolutional layer, pooling layer, and fully connected layer [22].

TABLE II DATA SET USED IN THIS STUDY

	Train	Train	Test	Test
Pneumonia	3875	40	390	10
SARS-CoV-2	930	40	930	10
Total	**4805**	**80**	**1320**	**20**

3.1. Data Set

Two open data sets were used within the scope of the study. The first of these data sets is Dr. Joseph Cohen et al. It was obtained from chest X-ray images of 930 COVID-19 patients created and shared on the GitHub platform [9]. The second one is the data set shared by Paul Mooney under the name of "Chest X-Ray Images (Pneumonia)" on the Kaggle platform [8]. The second data set contains 5856 images in total. All images in the data set are adjusted to 224 x 224 size. Information on the data set used in this study is summarized in Table 2.

The CNN models used within the scope of the study are InceptionV3, ResNet50, and InceptionResNet V2. These models can be briefly explained as follows:

3.2. Deep Learning Models Used in the Study

Explanations regarding the model used in the study are as follows:

InceptionV3: It is a kind of CNN-based model. In this model, the pooling steps are maximum and form a connected neural network structure at the last stage [24].

ResNet50: It is an improved version of the CNN model. By creating shortcuts between layers to solve the problem, provides convenience in the complex structure and prevents deterioration [25].

InceptionResNetV2: It is a kind of CNN-based model. In this model, it can be expressed as an estimated class probability list with 299 * 299 images to be trained in the ImageNet 2012 data set [26].

3.3. Experimental Setup

Python programming language was used in the training of the model proposed in the study [27]. The experiments carried out within the scope of the study were carried out using the Central Processing Unit (CPU), Graphics Processing Unit (GPU), or Tensor Processing Unit (TPU) hardware and the online cloud service. CNN models (ResNet50, InceptionV3, and Inception-ResNetV2) are pre-trained with random start weights by optimizing the cross-entropy function with the optimizer (1 = 0.9 and β2 = 0.999) called adaptive moment estimation (ADAM). Group size, learning speed, and a number of periods were experimentally set to 2, 1e-5, and 30 for all experiments, respectively. The data set used was randomly divided into two independent data sets, 800 and 40, respectively, for training and testing. The parameters used in the experimental process can be summarized in Table III:

TABLE III PARAMETER SETTINGS

Parameter	**Value**
Activation function	ReLU
Batch size	2
Learning rate	0.00001
Loss function	Binary
Optimizer	Adam, SGD, RMSProp

3.4. Performance Criteria

Deep learning criteria were used to examine the performance criteria of the model proposed in the study are:

$$Accuracy = \frac{TN + TP}{TN + TP + FN + FP} \quad (1)$$

$$Recall = \frac{TP}{TP + FN} \quad (2)$$

$$Sensitivity = \frac{TP}{TP + FP} \quad (3)$$

$$F1 - Score = 2 \times \frac{(Precision \times Recall)}{(Precision + Recall)} \quad (4)$$

TP, FP, TN and FN given in Equations (1) - (3) represent the numbers of True Positive, False Positive, True Negative and False Negative, respectively.

IV. RESULTS

This section describes the results obtained in this study. As mentioned earlier, three CNN models were used: InceptionV3, ResNet50, and InceptionResNetV2. More experiments were also performed to investigate different optimizers. In this study, three optimizers were tested: ADAM, SGD, and RMSProp optimizers.

The classification results obtained are summarized in Table IV. The highest classification accuracy was obtained for SGD optimizer with InceptionV3, ResNet50, and InceptionResNetV2 model. It produced 98.8% accuracy with just 20 epochs. This was followed by the RMSProp optimizer which resulted in 95.0% accuracy while ADAM optimizer produced 86.3% accuracy. In terms of the estimation level of the model applied in the test data set, in the case of using the SGD optimizer, the sensitivity, recall, and f1 score have an accuracy value of 1.00, while in the RMSProp optimizer, the sensitivity, recall, and f1 score are seen as 0.95. In ADAM optimizer, sensitivity is 0.88, recall and f1 score is 0.85.

The highest classification accuracy was obtained for SGD and RMSProp optimizer with InceptionV3, ResNet50, and InceptionResNetV2 model. It produced 98.8% accuracy with just 30 epochs. This was followed by the ADAM optimizer produced 82.5% accuracy. In terms of the estimation level of the model applied in the test data set, in the case of using the SGD and RMSProp optimizer, the sensitivity, recall, and f1 score have an accuracy value of 1.00, while in the ADAM optimizer, is 0.81, recall 0.70, and f1 score 0.67.

TABLE IV HIGHEST ACCURACY (%) OBTAINED FOR EACH OPTIMIZERS

Optimizer	**Epoch**	**Accuracy**	**Sensivity**	**Recall**	**F1Score**
SGD	20	98.8	100	100	100
RMSProp	20	95.0	95.0	95.0	95.0
ADAM	20	86.3	88.0	85.0	85.0
SGD	30	98.8	100	100	100
RMSProp	30	98.8	100	100	100
ADAM	30	82.5	81	70	67

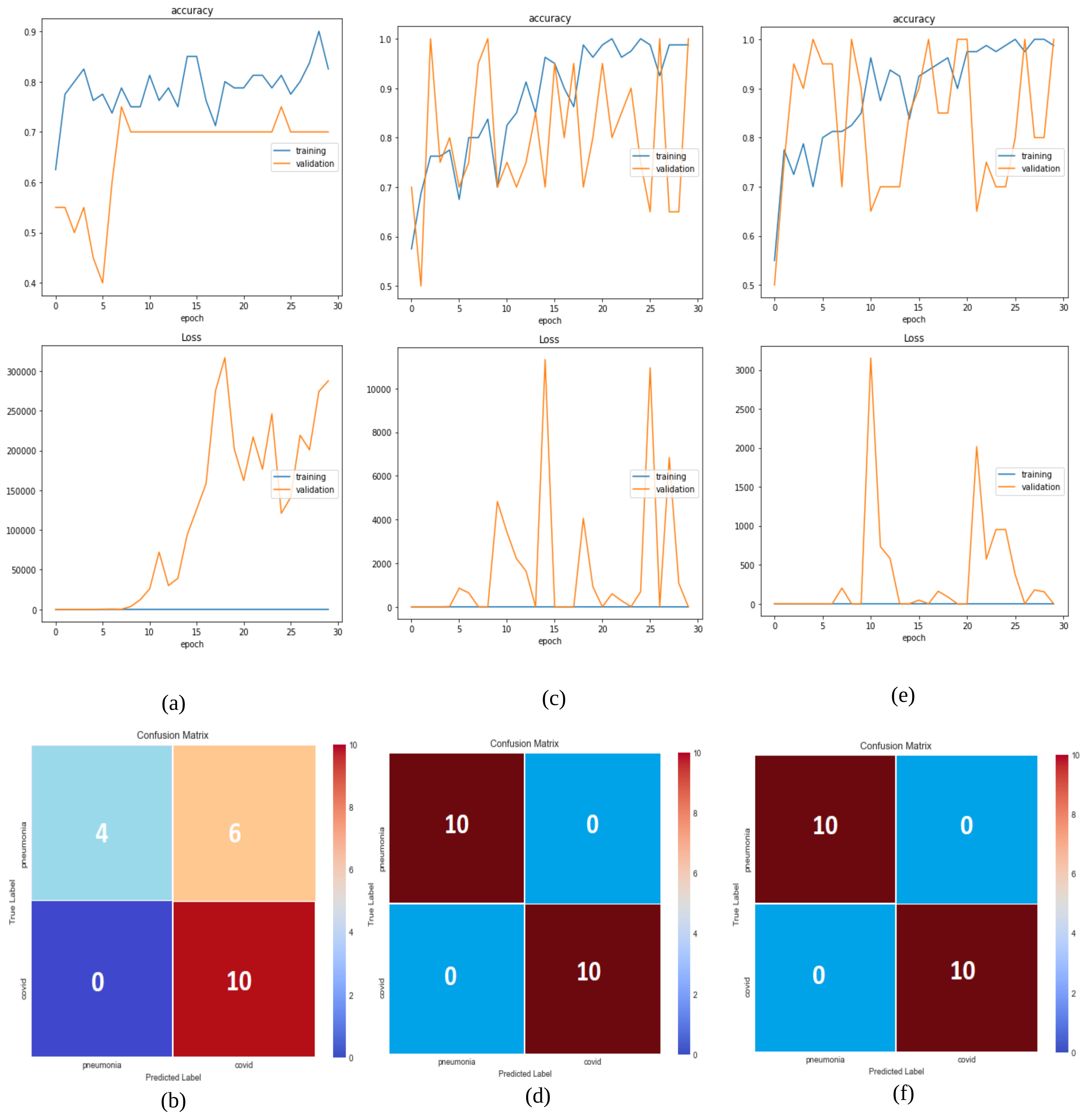

Figure 4. Comparison of results according to different optimizers (a) Accuracy and Loss Plots Using ADAM Optimizer (Epoch=30) (b) Correct and Prediction Matrix Using ADAM Optimizer (c) Accuracy and Loss Plots Using SGD Optimizer (Epoch=30) (d) Correct and Prediction Matrix Using SGD Optimizer (e) Accuracy and Loss Plots Using RMSProp Optimizer (Epoch=30) (f) Correct and Prediction Matrix Using RMSProp Optimizer

The overall summary of the results obtained for this study using CNN models with different optimizers can be seen from Fig. 4. a) shows the accuracy and loss obtained for the Adam optimizer for 30 epochs while b) shows the confusion matrix for the same optimizer. Similarly, c) and d) shows the accuracy/loss and confusion matrix for SGD optimizer. e) show accuracy and loss for RMSProp optimizer and f) shows the confusion matrix obtained using it. As it is clear that both SGD and RMSprop produced optimal results on our test data while the accuracy obtained for Adam optimizer was relatively lower than its two counterparts.

The models applied within the scope of the research have been compared some other well known models and the details regarding the comparison are summarized in Table V. In previous studies, data type, method, number of classes, and accuracy were compared.

In the study, it was aimed to reach the best result of the model applied to the data set of chest X-rays with the use of different optimizers. As a result of the findings obtained, it can be stated that SGD optimism stands out in the results obtained with three different optimizers for the model applied in the study. However, in the prediction process on the test data set, the RMSProp optimizer gave the best result and all predictions were obtained correctly.

TABLE V. COMPARISON WITH DIFFERENT STUDIES IN TERMS OF METHOD AND ACCURACY (%)

Study	Data Type	Method	No. of Classes	Accuracy (%)
Sahinbas and Catak [28]	X-Ray Images	VGG16, VGG19, ResNet, DenseNet, InceptionV3	2	80
Khan et al. [29]	X-Ray Images	CoroNet	4	89.60
Singh et al. [30]	X-Ray Images	MADE based CNN	2	92.55
Narin et al [27]	X-Ray Images	InceptionV3, ResNet50, ResNet101, ResNet152, Inception-ResNetV2	2	96.1
Proposed	X-Ray Images	InceptionV3, ResNet50, Inception-ResNetV2 (SGD Optimezer)	2	98.8 (epoch 20) 98.8 (epoch 30)
	X-Ray Images	InceptionV3, ResNet50, Inception-ResNetV2 (ADAM Optimezer)	2	86.3 (epoch 20) 82.5 (epoch 30)
	X-Ray Images	InceptionV3, ResNet50, Inception-ResNetV2 (RMSProp Optimezer)	2	95.0 (epoch 20) 98.8 (epoch 30)

These studies show that although there are different degrees of accuracy, different values of parameters such as epochs, the number of classes, and the model directly affect the classification accuracy. The literature showed that deep learning based approaches produced satisfactory results for identification of COVID-19 bases. However, less studies were conducted to distinguish between Covid-19 and Pneumonia cases.

CONCLUSION

The main purpose of this study is to facilitate the diagnosis of COVID-19 and pneumonia patients by training the images taken from open data sets of chest X-rays with the CNN-based model (InceptionV3, ResNet50, and InceptionResNetV2). In addition, every technological method that facilitates economic conditions has become very important during the current COVID-19 outbreak. It is aimed to reveal the difference between these two diseases with deep learning models within the scope of the study that the PCR tests required for the diagnosis of the COVID-19 epidemic are similar to pneumonia in terms of the burden of the economy and the lung effects of this disease.

We investigated different optimizers with the CNN models and evaluated their accuracy. The results indicate that the SGD optimizer with 20 epochs produced highest accuracy with 98.8%, followed by RMSProp and ADAM optimizers with 95% and 86.3%, respectively. However, when the epoch value was 30, SGD and RMSProp optimizers gave the best degree of accuracy with 98.8%, followed by ADAM optima with 82.5%.

In future we would like to extend the CNN models on relatively larger data sets and obtain high classification accuracy. In this context, the creation of regional data sets together with the contribution to open data sets may also allow deep learning to examine the effect of the epidemic disease such as COVID-19 according to the conditions of the region.

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