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Detection of Covid-19 in Chest X-Ray Images using Deep Learning

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Abstract: ***COVID-19 is a new kind of virus that was first emerged in China in December 2019 and now has 14,29,65,972 confirmed cases worldwide. Detection is a primary part of curb the coronavirus's spread, mainly based on test results such as PCR, RTPCR, high temperature, X-Ray, and CT-Scans, and Covid-19 symptoms. The research on detecting the coronavirus has gained momentum; scientists and doctors are working to find new techniques to detect the virus with higher accuracy and less time. Deep Learning and Transfer Learning play an essential role in the detection and classification of various abnormalities in medical image datasets with state-of-the-art convolutional neural networks. This paper proposes using seven transfer learning models to classify X-ray images into three classes: Normal, COVID-19, and Viral Pneumonia using a dataset of 15,189 X-ray images. We have used VGG-16, VGG-19, MobileNet-V2, DenseNet-121, Xception, ResNet-50V2, and Inception-V3 models. As a result, we achieved the best classification accuracy of 99.0%, 98.2%, 97.8%, 97.6%, 97.4%, 97.0%, and 95.3% respectively. It is assumed that the doctors and medical staff could use the paper's methods for diagnosing the COVID-19 disease with higher accuracy.***

Keywords: Covid-19, Viral Pneumonia, Transfer Learning, Data Augmentation, Chest X-ray, Deep Learning

I. INTRODUCTION

Coronavirus disease (COVID-19) is a contagious disease caused by a newly found virus in China in 2019, a part of a lethal virus family that includes SARS (Severe Acute Respiratory Syndrome) and MERS (Middle East Respiratory Syndrome). The SARS was detected in Southern China in 2003, and MERS was seen in Saudi Arabia in 2012 [1] [2]. Coronaviruses are a group of related RNA viruses that cause diseases in mammals and birds. In humans, they cause respiratory tract infections that can range from mild to deadly. SARS and MERS attack the respiratory system, but Covid-19 attacks other essential organs, such as the kidneys, liver, and lungs [3].

Many countries have decided to implement lockdowns to reduce the spread and fatalities as a second wave is started in many cities, which is more deadly and contagious. The number of active cases is growing rapidly; as of now, 30,46,149 deaths while 14,30,12,106 confirmed cases were reported. The covid-19 vaccines are also not available in many countries, and reports of shortage of vaccines due to limited manufacturing capacity are very concerning.

The COVID-19 virus is mainly transmitted through droplets formed when a corona-infected person coughs, sneezes, or exhales. These droplets are heavy and fall on surfaces, and spread when in contact with other persons. The virus then affected the respiratory system can be detected by X-Ray imaging of the chest [4]. The X-Ray images can provide fast and helpful information for diagnosing COVID-19 and Viral Pneumonia even without initial symptoms [5].

Deep Learning played a vital role in the medical field; image recognition and detection operation have improved in recent years due to the availability of medical datasets and access to powerful GPUs or TPUs that provide more complex neural network calculations. Pre-trained convolution neural network models used by transfer learning have provided a state-of-the-art performance for operations such as image classification with higher accuracy than classical neural networks.

The primary testing method for coronavirus is RTPCR, and it may take ten hours to two days to generate results. Reverse Transcription Polymerase Chain Reaction (RTPCR) test detects the viral RNA from sputum or nasopharyngeal swab. Therefore, a fast system to test future COVID patients within minimal time and higher accuracy is needed. In response to the pandemic outbreak and to curb the spread, many researchers from various backgrounds worldwide actively engage in finding effective diagnostic methods and vaccines for treatment for covid patients.

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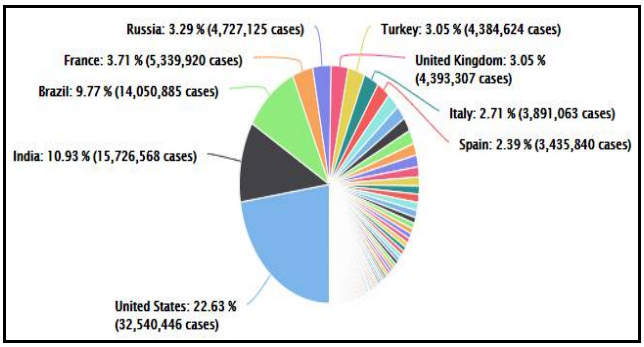


FIG-1: Distribution of Covid-19 Cases Worldwide

Figure-1 shows the distribution of corona cases as of 21 April 2021; the transmission of the virus increases day by day. The researchers and doctors are working on Deep Learning and Computer Vision techniques to explore new methods to curb the spread of the virus and cure the virus. The identification of covid-19 using X-ray can play an important role in corona tests. The doctors could use chest x-rays data to find the difference between viral pneumonia and coronavirus patients, as it is fast and accurate compared to other Covid-19 tests. If the results in positive for covid, then the patient can go for the RTPCR test. This paper used transfer learning, a deep learning method that focuses on using pre-trained data to detect covid positive patients by chest x-ray [6].

II. MATERIALS AND METHODS

A detailed explanation of the proposed methodology, dataset, and model design for Covid-19 detection is given in this section.

A. Dataset

As COVID-19 is a new kind of virus, it is tough to find the dataset and images of the coronavirus pandemic, and the situation is terrible to handle the outbreak. This research is significant because many X-ray images that are available open-source are used for disease detection. It is also crucial to have a good dataset with chest x-ray images of confirmed covid-19 patients and normal patients for classification. The dataset used in this study is publicly available and is collected from Kaggle called Covid-19 Radiography Database [7]. It contains 15,189 chest X-ray images from a team of researchers from Qatar University and the University of Dhaka [8] [9], along with contributors from Malaysia's medical experts. They have created a dataset of chest X-ray images for COVID-19 cases along with Normal and Viral Pneumonia images. In summary, a total of 3,628 COVID-19 images, 10,204 Normal images, and 1,357 Viral Pneumonia images are prepared to train, validate, and test the models proposed, as shown in Table-1 below.

Categories	Training	Validation	Testing
Covid-19	2,892	724	12
Normal	8,153	2,039	12
Viral Pneumonia	1,076	269	12
Total	12,121	3,032	36

Table-1: Number Of Allocated Images Data

B. Related Work

From the beginning of the pandemic, many researchers are working to discover many methods for identifying covid-19 and its cure. Transfer Learning helps decrease the computational overhead and is shown to be the most promising method in many deep learning applications related to the medical field. This section briefs some of the recent works done on COVID-19 detection using Chest X-rays and different models used to detect covid positive cases with higher accuracy successfully.

The idea of using chest x-rays in the prediction of covid-19 came from the initial approaches which are used in pneumonia detection from chest x-rays using deep neural networks [10]. Biraja Ghoshal et al. shows that deep learning for disease detection focuses on improving the accuracy of classification in their paper. They investigated how drop weights-based BCNN can figure this uncertainty [11].

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Mehmet Sevi et al. [12] showed in their research paper that they use transfer learning models VGG-16 and VGG-19 to detect Covid-19 positive patients from chest X-Ray images and achieved an accuracy of 93% and 95%, respectively. In [13], the researchers have shown two approaches to detect Covid-19 from chest x-ray images; the first approach is to build a convolutional neural network from scratch and the second approach is to use transfer learning models. They managed to get the highest test accuracy of 90%.

Deepak Ranjan Nayak et al. proposed a Deep Learning assisted automated method using X-ray images for early diagnosis of COVID-19 infection. They used eight different transfer learning models to classify Covid-19 cases from normal cases in the chest x-ray dataset, and the best performance is achieved with an accuracy of 98% [14].

Cohen et al. [15] proposed a neural network model for predicting and measuring the severity of pneumonia in general and covid-19 chest x-ray images and monitoring the patients' treatment especially in the ICU.

C. Data Preprocessing

Data Preprocessing is the crucial step in deep learning models to build an effective convolutional neural network, which requires correct input data format. This research paper used Data Normalization and Data Augmentation to achieve the best result from transfer learning models.

A CNN model is possible to learn faster, and the gradient descent is more likely to be stable with the help of Data Normalization [16]. It is an important step that ensures each input parameter has a similar data distribution, making convergence faster while training the network. The pixel values in the image input need to be positive and have been normalized between in the range 0–1. The dataset used in this paper has RGB images, and the rescaling was done by multiplying every image's pixel value by 1./255.

The Convolutional Neural Network models need a large amount of dataset to achieve higher accuracy and perform better on relevant datasets using transfer learning methods. Data science researchers have used the Data Augmentation technique, which helps to increase the number of images by using a set of data transformations while preserving original class labels of the images. It is done to enlarge the dataset and expose the neural network to various variations of the images. It makes it more likely that your model recognizes objects when they appear in any form and shape [17].

In this paper, the available Covid-19 chest X-ray images are very few, i.e., 3,628. While working on the medical images using Deep Learning models, this has been a primary concern that a limited amount of data is not sufficient to get better performance. In this paper, the images were augmented using the data augmentation such as rotation of all images by 5 degrees, scaled images by 15%, images were flipped horizontally, heights and widths of images shifted by 10%, and zooming the images by 10% as shown in figure 2 below.

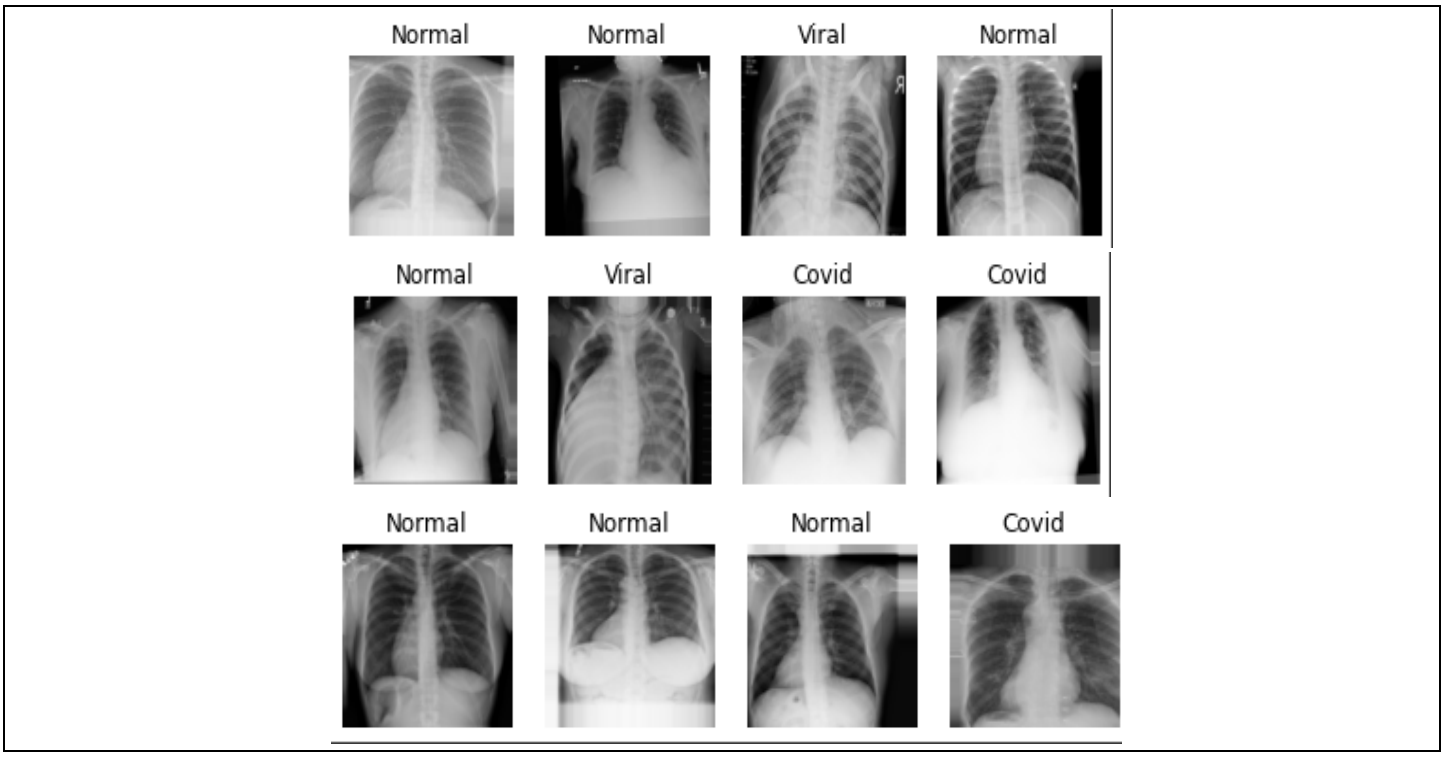


Fig-2: Random Sample Choosen From Dataset

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D. Proposed Methology

Convolutional neural network models need a massive amount of data to train and achieve state-of-the-art performance. In addition to the massive amount of data, hyperparameters such as learning rate, drop-out, batch normalization, optimizers, loss function, number of output layers, and activation functions play an important role in achieving the best results in a shorter time. It would not be easy to build these models from scratch to predict covid-19 cases due to the long training period. So, in this situation, the concept of the Transfer Learning method can be helpful because it is trained on millions of data and is used to solve a similar task with relatively fewer data.

In this paper, we proposed seven pre-trained CNN models listed as VGG-16 [18], VGG-19 [19], MobileNet-V2 [20], ResNet-50V2 [21], Xception [22], Inception-V3 [23], and DenseNet-121 [24] which have been used for classification in between COVID-19 cases, Normal cases, and Viral Pneumonia cases. These pre-trained models help reduce the requirement for a large dataset and the longer training time required by deep learning methods trained from scratch. Keras provides access to many top-performing pre-trained models trained on ImageNet data and includes functions to load a model with or without the pre-trained weights. The first time a pre-trained model is loaded, Keras will download the required model weights, which may take some time. By default, the model expects color input images to be rescaled to the size of 224×224 squares.

In Fine-Tuning these models, the last layer was removed during download, then a new Fully Connected (FC) layer was added at the end of the downloaded models with an output size of three that represents three separate classes (Normal, Viral Pneumonia, and COVID-19). Only the last final FC layer was trained in models and frozen all other layers with pre-trained weights. In fine-tuning, the hyperparameters such as learning rate, dropout, optimizers play a crucial role in achieving high accuracy in these deep learning models. We used a Learning Rate of 1e-3, number of Epochs to 30, Optimizer set as Adam, Loss Function set to categorical cross-entropy, Batch size set to 32. Also, Early Stopping is used on validation loss to stop the training and avoid overfitting in models.

Models	Total Number of Layers	Parameters (in millions)	Input Layer Size
VGG-16	18	27	(224,224,3)
VGG-19	21	32	(224,224,3)
MobileNetV2	153	74	(224,224,3)
InceptionV3	310	88	(299,299,3)
DenseNet121	410	32	(224,224,3)
Xception	131	72	(224,224,3)
ResNet-50V2	189	74	(224,224,3)

Table-2: Pre-Trained Cnn Models Architecture

In table-2, the architecture of seven pre-trained models is shown, which was used in this paper. These models were trained using ImageNet data which have millions of images of different categories. The architecture table shows the total number of layers, total number of parameters in millions, and the input layer size. The pre-trained models can be used directly in a new neural network model. In this usage, the pre-trained weights can be frozen so that they are not updated as the new model is trained to get better accuracy on test datasets.

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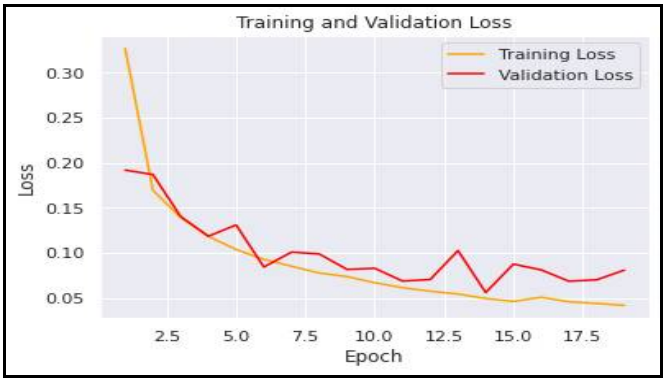
III. RESULT AND DISCUSSION

We performed a detailed analysis on the prediction of COVID-19 from the X-ray dataset using seven pre-trained convolutional neural network models, namely VGG-16, VGG-19, MobileNet-V2, DenseNet-121, ResNet-50V2, Xception, and Inception-V3. In this research paper, we tested the various hyperparameters associated such as learning rate, optimizers, loss functions with these pre-trained models. table-3 shows the accuracy and loss of training and validation.

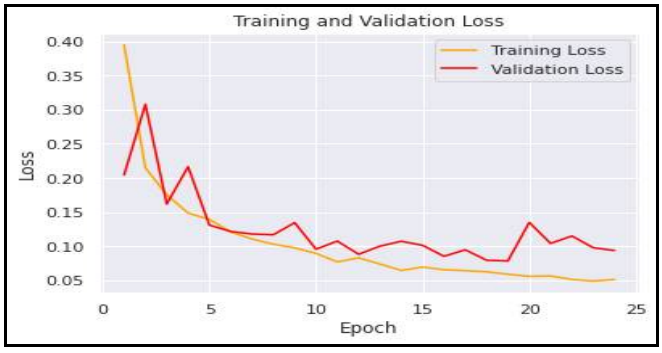
Model	Train Acc%	Train Loss%	Val Acc%	Val Loss%
VGG-16	99.00%	3.90%	98.91%	5.59%
VGG-19	98.20%	4.82%	97.30%	7.89%
MobileNet-V2	97.82%	6.05%	96.67%	10.39%
DenseNet-121	97.65%	6.73%	96.90%	8.53%
Xception	97.44%	7.87%	95.35%	14.21%
Resnet-50V2	97.02%	7.80%	95.65%	12.77%
Inception-V3	95.30%	13.26%	95.42%	12.63%

Table-3: Training Performance Of All Proposed Models

The primary purpose of this research is to make decisions for the patients that can help reduce the spread of COVID-19 infection. The proposed model is cost-effective and can aid radiologists in verifying their decisions. In the next part, the Loss convergence plot obtained for different CNN architectures, i.e. the training loss and validation loss and shown in figure a, b, c, d, e, f, g.

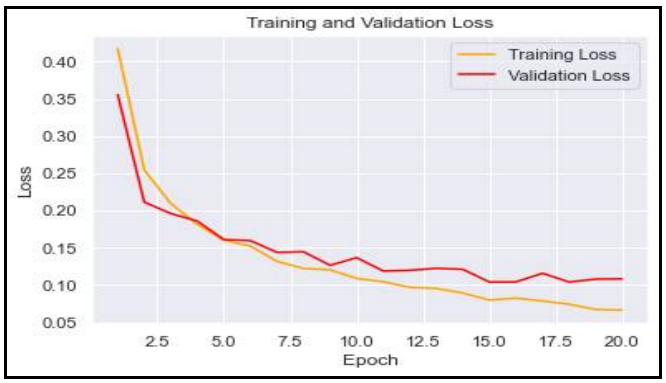


(a) - VGG-16

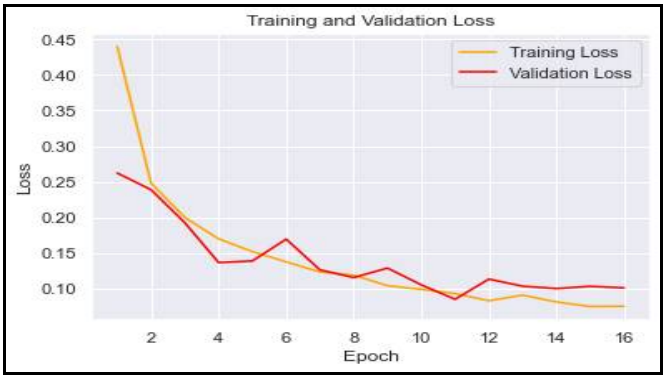


(b) - VGG-19

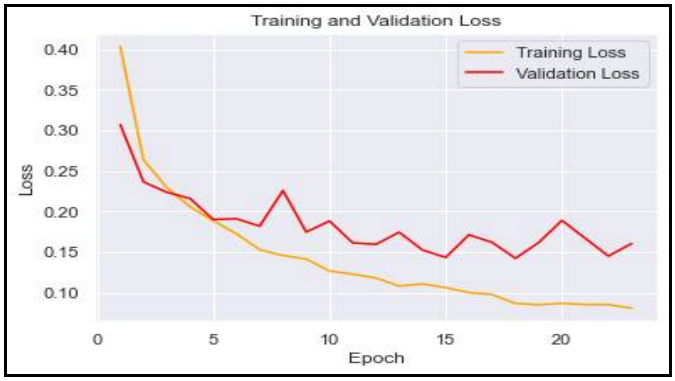
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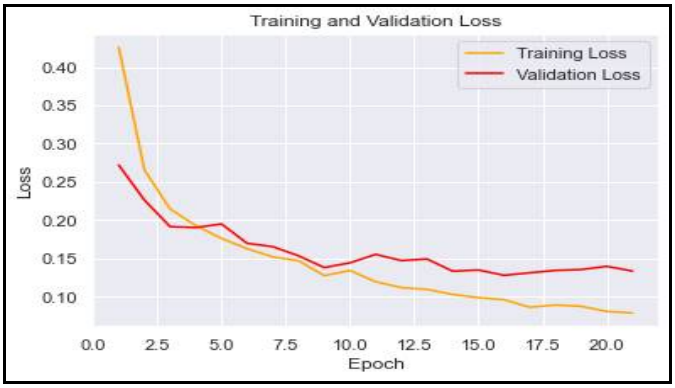
(c) - MobileNet-V2



(d) - DenseNet-121

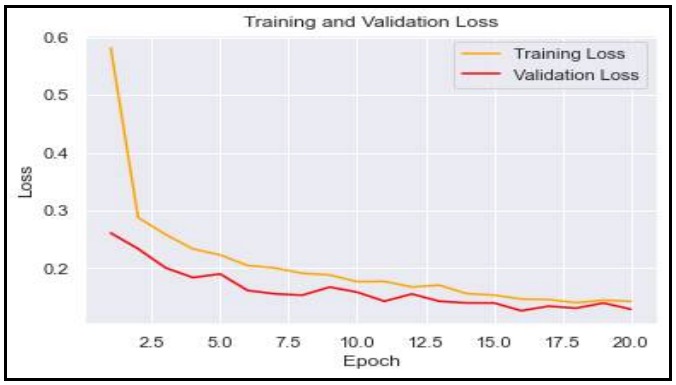


(e) - Xception



(f) - ResNet-50V2

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(g) - Inception-V3

In a deep learning model the values like precision, recall, f1-score are considered as performance metrics since they are used to evaluate the model performance.

1) *Precision:* It quantifies the number of positive class predictions that actually belong to the positive class.
2) *Recall:* It quantifies the number of positive class predictions made out of all positive examples in the dataset.
3) *F1-score:* It provides a single score that balances both the concerns of precision and recall in one number.
4) *True Positive:* It's an outcome where the model correctly predicts the positive class.
5) *True Negative:* It's an outcome where the model correctly predicts the negative class.
6) *False Positive:* It's an outcome where the model incorrectly predicts the positive class.
7) *False Negative:* It's an outcome where the model incorrectly predicts the negative class.

Table a, b, c, d, e, f, g shows performance and confusion matrix of all seven models on test dataset such as true positive, true negative, false positive, false negative, precision, recall, and f1-score.

Predicted Class/ True Class	Covid	Normal	Viral	Precision	Recall	F1-Score
Covid	12	0	0	1.00	1.00	1.00
Normal	0	12	0	1.00	1.00	1.00
Viral	0	0	12	1.00	1.00	1.00

(a) - VGG-16

Predicted Class/ True Class	Covid	Normal	Viral	Precision	Recall	F1-Score
Covid	11	1	0	1.00	0.92	0.96
Normal	0	12	0	0.92	1.00	0.96
Viral	0	0	12	1.00	1.00	1.00

(b) - VGG-19

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Predicted Class/ True Class	Covid	Normal	Viral	Precision	Recall	F1-Score
Covid	11	1	0	1.00	0.92	0.96
Normal	0	11	1	0.92	0.92	0.92
Viral	0	0	12	0.92	1.00	0.96

(c) - MobileNet-V2

Predicted Class/ True Class	Covid	Normal	Viral	Precision	Recall	F1-Score
Covid	11	1	0	1.00	0.92	0.96
Normal	0	12	0	0.92	1.00	0.96
Viral	0	0	12	1.00	1.00	1.00

(d) - DenseNet-121

Predicted Class/ True Class	Covid	Normal	Viral	Precision	Recall	F1-Score
Covid	10	2	0	1.00	0.83	0.91
Normal	0	12	0	0.86	1.00	0.92
Viral	0	0	12	1.00	1.00	1.00

(e) - Inception

Predicted Class/ True Class	Covid	Normal	Viral	Precision	Recall	F1-Score
Covid	10	2	0	1.00	0.83	0.91
Normal	0	12	0	0.86	1.00	0.92
Viral	0	0	12	1.00	1.00	1.00

(f) - ResNet-50V2

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Predicted Class/ True Class	Covid	Normal	Viral	Precision	Recall	F1-Score
Covid	10	2	0	1.00	0.83	0.91
Normal	0	12	0	0.86	1.00	0.92
Viral	0	0	12	1.00	1.00	1.00

(f) - Inception-V3

IV. CONCLUSION

This Research Paper solves the lack of analysis of X-ray images to find positive covid-19 cases in this fast-spreading pandemic. It would act as a tool for doctors and radiologists to detect covid in a couple of minutes and, if predicted positive, then go for RT-PCR test. We proposed a deep learning method using extracted features from seven different transfer learning models for classifying covid-19, viral pneumonia, and normal patients using chest x-rays. VGG-16 is the most successful model with a 99% accuracy rate, followed by VGG-19, MobileNet-V2, DenseNet-121, Xception, ResNet-50V2, and Inception-V3. The Inception-V3 model is the most unsuccessful method for the covid-19 detection. The result we achieved by the transfer learning models are compared with the related work section that has shown recently proposed Deep Learning methods for automated COVID-19 diagnosis using chest X-ray images. It is observed that the method we proposed in this research paper achieved higher performance than the other existing methods.

There will be more successful deep learning models in the future that work with better accuracy and lesser time. It will also be trained with larger data sets and will propose different ways to detect covid-19.

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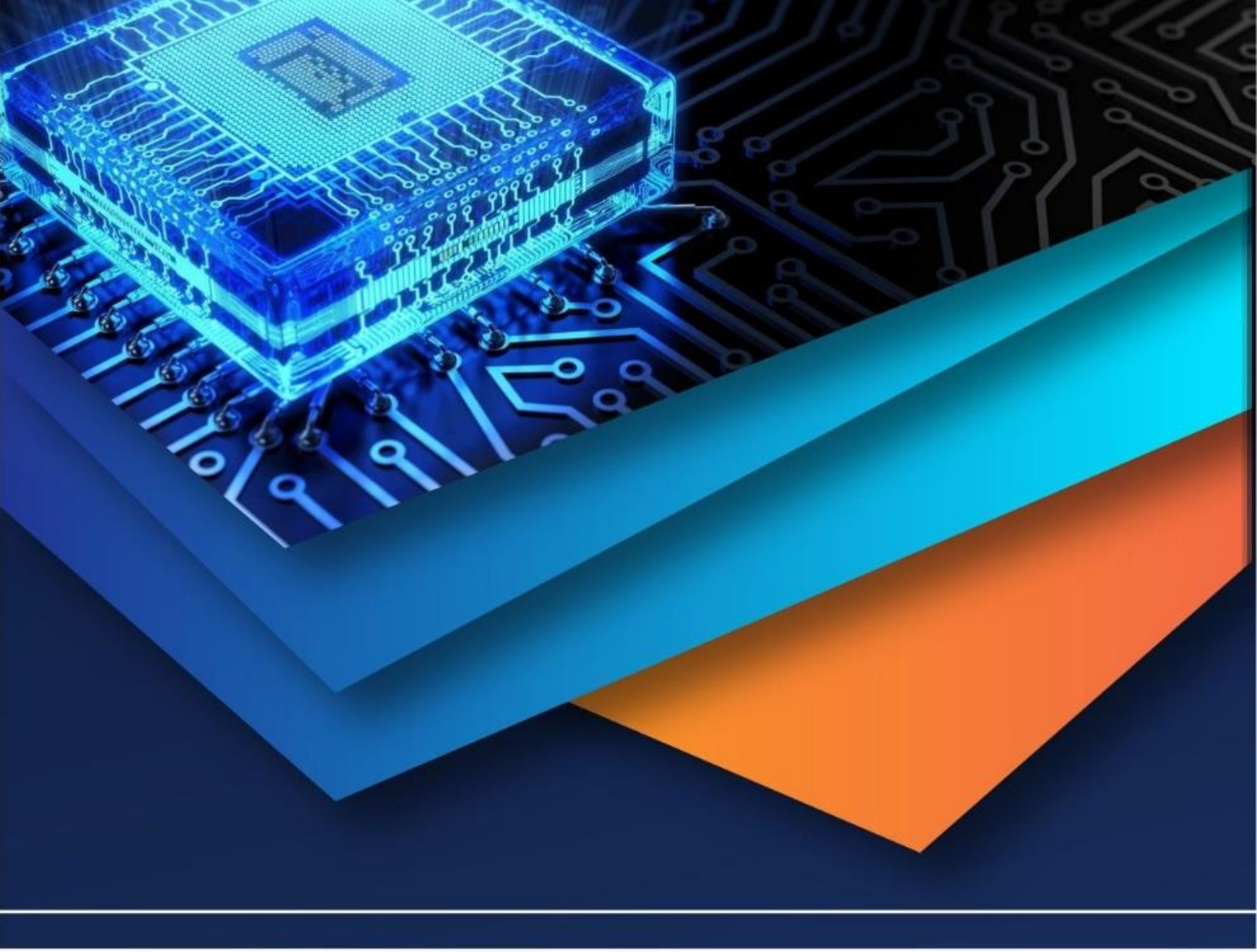
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