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COVID-19 Detection using Chest X-Ray Images through a Convolutional Neural Network and Transfer Learning

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Abstract: The ongoing novel corona virus has spread all over the world and became a pandemic. This pandemic situation has led to a major crisis in healthcare systems and the global economy. As Covid-19 positive patient's increasing day by day, the crucial task is to detect and monitor disease efficiently and facilitate the results of Covid-19 positive patients to cure them as soon as possible. Currently used RT-PCR (Reverse transcription-polymerase chain reaction) testing method act as a goldmine for detecting Covid-19. But the total turnaround time required for Disease diagnosis is very large. This long turn-around time sometimes leads to patient deaths. To avoid that and detecting Covid-19 positive patients in a less time ,author proposed a method in this paper that uses Chest x-ray images for patient diagnosis and disease classification. Deep learning architecture called Convolutional neural network helps in diagnosis of patient. The tremendous success of the Convolutional neural network at image processing tasks in recent years extremely increased the use of electronic medical records and diagnostic imaging. To train and test the neural model the paper used a publicly available dataset that contains COVID-19, pneumonia, and normal patient Chest X-ray images. Also for experimental analysis a CovidNet20, Convolutional architecture was developed for disease classification along with transfer learning DenseNet121 pretrained model used for training and testing of the classification model. The proposed model able to differentiate COVID-19 and normal images as binary classification with 100% and 99% accuracy on DenseNet121 and CovidNet20 model. And, on multiclass classification with COVID-19, Normal and Pneumonia as classes Densenet121 gives 97% and CovidNet20 gives 98% accuracy.
Keywords: Coronavirus, COVID-19, Convolutional Neural Network, Transfer Learning, Deep Learning.

I. INTRODUCTION

A Corona virus is a group of viruses that can cause both Animals and Humans. The new strain of Coronavirus is called SARS-CoV-2 i.e. severe acute respiratory syndrome corona virus-2. This virus causes COVID-19. The first human case of COVID-19 was first reported in Wuhan City, of China in December 2019. And from China, it's spread all over the world. According to WHO, SARS-CoV-2 is a viral disease. So when someone breathes out or coughs, tiny droplets containing the virus can enter the mouth or nose of someone, causing an infection to occur. Those who are infected by COVID-19 suffer from a fever, breathlessness, a cough, muscle pain, chills, and a net loss of taste and smell.

Since COVID-19 attacks epithelial cells of our body that are present in the respiratory tract, we can use x-rays to analyze the health of the patient's lungs. Currently, reverse transcriptase-polymerase chain reaction (RT-PCR) testing is used which can detect SARS-CoV-2 from respiratory specimens collected through nasopharyngeal or oropharyngeal swabs. While RT-PCR testing is one of the methods as it is highly specific to its test cases. But it is very time-consuming and requires a complex manual process. However, the sensitivity of RT-PCR testing is highly variable and has not been reported consistently and clearly. So to increase the sensitivity of testing and to use limited resources effectively the given paper uses chest X-Ray images to detect COVID-19 infection in the patients showing symptoms of SARI.

There are several advantages of COVID-19 detection through X-ray images rather than RT-PCR testing. X-ray imaging is more widespread and cost-effective than conventional diagnostic tests. X-ray images do not require any transportation, thus making the diagnostic process extremely quick. Also, an X-ray imaging system is available in most hospitals that reduce the additional cost of resources. The main contribution of this paper is in using a Convolutional neural network a deep learning framework to predict COVID-19 from Chest X-ray images. Unlike the machine learning approach that involves parameter tuning and recognition of images as 2 separate task, the paper uses end-to-end deep learning framework that directly predicts the COVID-19 disease from provided images without any need for feature extraction.

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The paper is organized as follows, Section II covers literature review or previous work is done using Convolutional neural network on Covid-19 x-ray detection. Section III shows information about x-ray data that are collected from GitHub and Kaggle. Section IV and V presents experimental results and model architecture that has been performed on DenseNet121 and CovidNet20 model. Finally, section VI presents the conclusion.

II. RELATED WORK

This part conducts a survey on the recent work that has been proposed in the Detection of COVID-19 using X-ray images. Razzak et al[1] proposed a study on Convolutional and Deep neural networks in image segmentation and also provide information on challenges that occur during collecting the data in medical diagnosis. MangalS et al[3], proposed a model for detecting Covid-19, normal, bacterial, and viral pneumonia with the help of Deep learning. The main focus of this study is to accurately classify all diseases. Paper [3] and [21] provides a method that helps to improve model performance by applying the ImageAugumentation technique on original data. Augmentation generates additional images by setting parameters like horizontal flip, vertical flip, shear range, and zoom range to certain values and also helps to avoid an imbalanced dataset. The [6] paper has presented a study on transfer learning architecture of convolution neural network for COVID-19 detection and presents model accuracy by performing comparative study on all architectures. Paper [11],[12] and [15] are provided actual implementation of VGG, ImageNet and DenseNet architecture. All these algorithms are part of ImageNet competition and Because of their deep layers, they have been used in a wide range of problems from classification, segmentation, face recognition, to super resolution and image enhancement.

III. DATASET AND EVALUATION

For the experiments, several sources of X-rays were accessed. Firstly, the GitHub repository was analyzed for X-ray data. All COVID-19 X-ray images along with MERS-CoV (Middle East Respiratory Syndrome) and SARS(Severe Acute Respiratory Syndrome) are collected from chest-x-ray-dataset ,the public GitHub[16] repository shared by Dr. Joseph Cohen, a postdoctoral fellow at the University of Montreal. This dataset contains a mixture of chest X-ray and CT images. But for purpose of the given study, only X-ray images were selected along with the posterior-anterior view. It also contains some meta-data about each patient, such as sex and age. A total of 496 images of Covid-19 X-rays were taken from this repository. Secondly, the Kaggle [17] dataset was used for Chest X-ray images of Normal and Pneumonia patients (including viral and bacterial). It contains 1583 normal and 4273 pneumonia patient Chest x-rays.

For purpose of analysis, two sets of data are prepared. The first set is used to perform binary classification as it contains x-ray images of Normal and COVID-19 patients. The dataset has 496 images of COVID-19 patients taken from chest-x-ray-dataset and 1583 images of Normal patients taken from Kaggle dataset.

Table 1: Data evaluation for binary classification

Split	COVID-19	NORMAL
Training Set	396	1072
Test Set	80	215
Validation Set	20	54

And the second dataset is used to perform multiclass classification as it contains both viral and bacterial pneumonia as one PNEUMONIA class. The other two classes named COVID-19 and NORMAL remain the same. The third dataset contains a total of 6110 x-ray images taken from both the [16][17] above 2 sources.

Table 2: Data evaluation for Multiclass classification

Split	COVID-19	NORMAL	PNEUMONIA
Training Set	396	1072	3418
Test Set	80	215	648
Validation Set	20	54	207

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IV. METHODS

Classifying images in medical image diagnosis is a very crucial task. To accurately classification of COVID-19 disease from other diseases, the given paper uses 2 methods. The first approach is to use of popular state-of-architecture of CNN named DenseNet121.This architecture is part of the ImageNet competition. A second one is using CovidNet20, a Convolution architecture of 20 layers deep which are developed for disease classification.

The methodology used during training the model:

A. As DenseNet121 is build to classify 22000 different classes of images in ImageNet Competition, training those networks require a huge amount of image data. But in our experiment a limited number of X-ray images are available, to avoid classification problems because of less data, the technique called ImageDataAugumentation was used to artificially expand the size of the training dataset. Augmentation not only improves performance and model stability but also to avoid overfitting problem.

B. Instead of training the model from scratch and tuning the hyperparameter for accurate classification. Paper used transfer learning approach. In transfer learning, the trainable weights of existing models are frozen and only the last dense layer is changed according to classification units.

V. PROPOSED MODEL AND ITS ARCHITECTURE

The 2 models are used in this experiment, which follow Convolution neural network layers pattern for model parameters tuning.

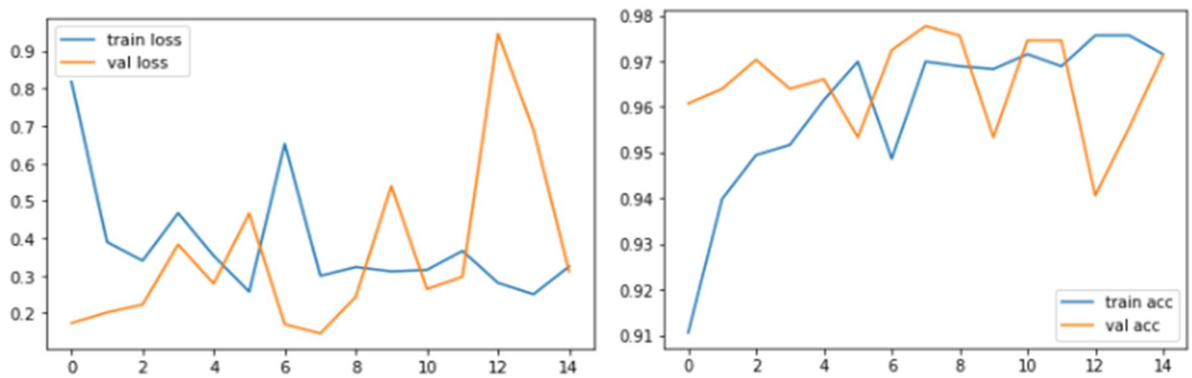
1) *CovidNet20:* The 1st model CovidNet20 that have developed in this experiment has a total of 20 layers. In this, 2 Batch Normalization layer is used to standardize the inputs and to initialize weights easily which helps in reducing training time and increasing the stability of the model.4 Conv2D layers are used to extract features from images with 3x3 kernel size. The Max pool method is used to downsize an input by taking the maximum region determined by its filters. Also, the ReLu function used (Rectified linear activation function) to increase the non-linearity by converting negative values to zero. And also helps to overcome the vanishing gradient problem. Finally, all cells are flattened down to a single axis and a Dense layer is applied along with the softmax activation function for multiclass classification.
2) *DenseNet121:* DenseNet [15] is one of the most popular CNN architecture written by Gao Huang, Zhuang Liu, Laurens van der Maaten, and Kilian Q. Weinberger which was the winner of the 2017 ImageNet competition. In DenseNet, each layer obtains additional inputs from all preceding layers and passes on its feature-information to all subsequent layers. Since each layer receives feature maps from all preceding layers, the network can be thinner and compact, i.e., the number of channels can be less. So, has higher computational efficiency and memory efficiency.

VI. EXPERIMENTAL RESULTS

1) *Model Hyper-Parameters:* For the experiment, Model epochs are fine-tuned to 15. The batch size is set to 32, and the ADAM optimizer is used to optimize the loss function, with a learning rate of 0.0001. All images are down-sampled to 224x224 before being fed to the neural network. And For sensitivity and specificity, 0.90 thresholds were set in all 3(training, validation, and testing) phases. All our implementations are done in Google colab, and code is publicly available at https://github.com/akshaypatil314/Covid-Detection-Using-X-ray.git this repository.
2) *Model Performance:* Experiments are performed to detect and classify COVID-19 using X-ray images in two different scenarios. Firstly data is trained on both the models (CovidNet20 and DenseNet121) to classify X-ray images into 3 categories COVID-19, Normal and Pneumonia. Secondly, models are trained to detect 2 classes COVID-19 and normal. After that, Model performance is calculated in both the scenarios where images are train with and without Image Augmentation. During training the model real-time ImageDataAugumentation technique apply on DenseNet121 to avoid misbalancing issue of data.By setting parameters like horizontal flip set to true and shear and zoom range set to 0.20 for both multiclass and binary class classification. Table 3 shows that DenseNet121 has gives 97.56% accuracy on training data along with 97% precision and recall in multiclass classification. Binary class shows 100 % accuracy on both training and testing phase with 100% sensitivity. It is always important that model will perform accurate on testing and validation phase because during this phase actual performance of the model was calculated.

Table 3:DenseNet121 Performance on Multiclass Classification DenseNet121

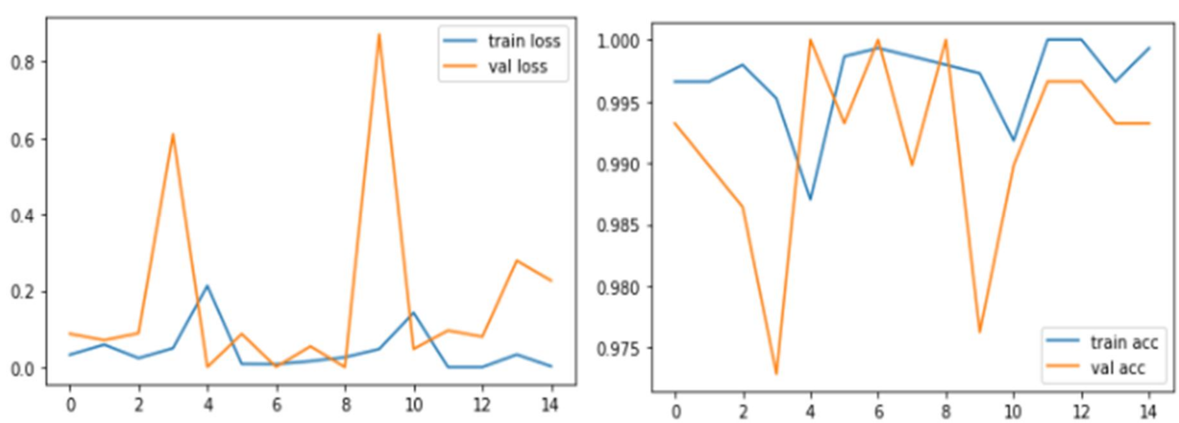
Phase	Accuracy	Precision	Recall	Sensitivity	Specificity
Training	0.9756	0.9756	0.9756	0.9834	0.9918
Validation	0.9555	0.9555	0.9555	0.9682	0.9841
Test	0.9537	0.9537	0.9537	0.9608	0.9804



Fig(1) Training and Validation accuracy and loss on Multiclass classification of DenseNet121 model

Table 4 :DenseNet121 Performance on Binary Classification DenseNet121

Phase	Accuracy	Precision	Recall	Sensitivity	Specificity
Training	1.0000	1.0000	1.0000	1.0000	1.0000
Validation	0.9966	0.9966	0.9966	1.0000	0.9966
Test	1.0000	1.0000	1.0000	1.0000	1.0000



Fig(2)Training and Validation accuracy and loss on Binary classification of DenseNet121 model

3) *Model Performance on CovidNet20:* Batch Normalization layer in CovidNet20 really impacts overall performance. Table 5 and 6 shows 97% and 99% accuracy in both testing phase of multiclass and binary class classification of CovidNet20 model. From 109 images of COVID-19 as shown in Fig (4),CovidNet20 accurately predicted 100 images accurately during testing phase in multiclass classification and from 391 images in Fig(6) binary set of covid-19 all are predicted correctly during testing the model.

Table 5:CovidNet20 Performance on Multiclass Classification

Parameter	Training	Validation	Testing
Accuracy	0.9879	0.9951	0.9700

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	Normal	Pneumonia	Covid-19
Normal	1055	22	0
Pneumonia	0	3414	2
Covid-19	0	0	395

Fig (3) Confusion matrix on Validation Data

	Normal	Pneumonia	Covid-19
Normal	249	12	3
Pneumonia	10	841	6
Covid-19	0	1	100

Fig (4) Confusion matrix on testing Data

Table 6:CovidNet20 Performance on Binary Classification

Parameter	Training	Validation	Testing
Accuracy	0.9980	1.0000	0.9900

	Normal	Covid-19
Normal	261	2
Covid-19	0	105

Fig(5) Confusion matrix on Validation Data

	Normal	Covid-19
Normal	1078	0
Covid-19	0	391

Fig(6)Confusion matrix on testing Data

VII. CONCLUSION

From the above experiment, it is concluded that a deep learning framework called a Convolutional neural network is able to classify COVID-19 disease from Chest X-ray images. The main challenge in this experiment is to training the model on a limited dataset and tuning the parameters. But even we have less data, Image Augmentation helps us to generate more images during model training and improve the overall performance of the model. From the above experiment, it is observed that DenseNet121 with image augmentation technique shows 97.56% accuracy on training data for multiclass classification, and for binary class, it shows 100% accuracy. However, in the case of original data without image augmentation, the CovidNet20 model shows 98% accuracy on multiclass and 99% accuracy on binary class classification. The presented work shows that advances in computer vision algorithm and especially in artificial intelligence really helps in medical image diagnosis. In this Covid-19 situation used of above, the deep learning method helps doctors for pattern finding and disease classification as an alternative solution for faster patient diagnosis.

VIII. ACKNOWLEDGEMENT

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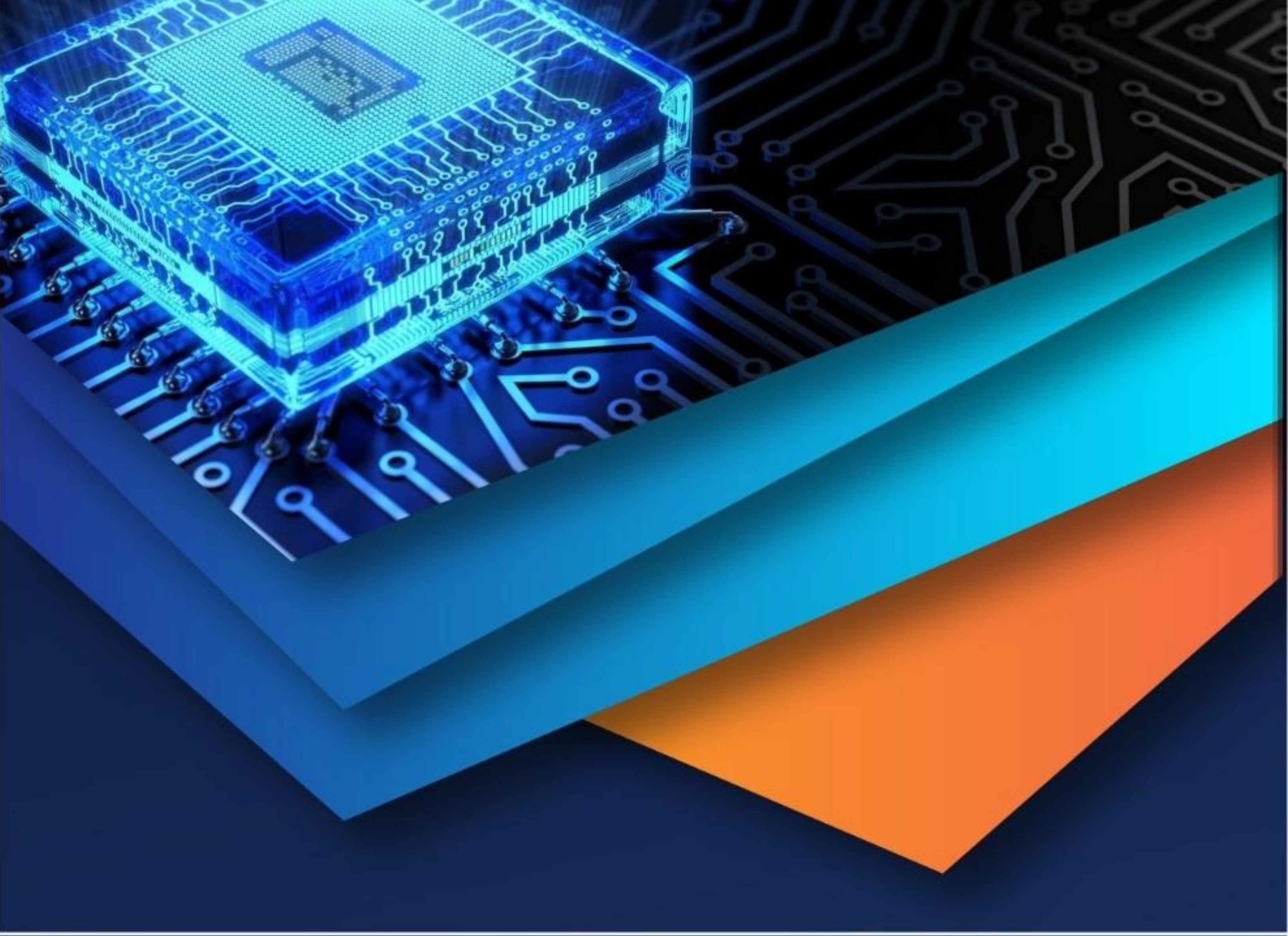

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