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Covid-19 Detection & Classification of chest X-rays using Deep Learning

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Abstract: ***The deadly Covid-19 virus, also known as the Coronavirus has affected the entire world in a short period of time. This pandemic has affected a lot of people in the entire world and caused many deaths. In these difficult times, it is important for the doctors and the medical researchers to differentiate accurately between positive cases and negative cases. This CNN (Convolutional Neural Network) model will allow us to classify X-ray images into positive cases and the normal ones. This dataset is collected from different public sources as well as from some hospitals and physicians. Our goal is to take help from these X- ray images and develop a model where it predicts and classifies the infected cases.***
Keywords: CNN, Prediction, Classification, Features, Training, Testing, Deep Learning

I. INTRODUCTION

Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered coronavirus. The COVID-19 virus spreads primarily through droplets of saliva or discharge from the nose when an infected person coughs or sneezes, so it's important that you also practice respiratory etiquette (for example, by coughing into a flexed elbow).

The most common path for the virus to be transmitted is through respiratory droplets and close contact. Coronavirus is acquired either by inhaling these respiratory droplets or by touching the surface that is infected and then touching the mouth, nose, or eyes. Recent studies have shown that this virus can also be transmitted from people who have no symptoms of this disease. Most of the coronavirus-infected population show mild pneumonia-like symptoms such as fever, cold, sore throat, fatigue, headache, loss of smell. Still, in some cases, severe symptoms such as breathing difficulties have been observed.

Some researchers say that the chest X-ray procedures such as CT scans and X-rays may prove to be an efficient tool for diagnosing and tracking of COVID-19 cases. Moreover, using a chest radiograph for accurate classification of positive and negative cases can be very helpful for the medical researchers as well as the doctors. A chest radiograph, also called a chest X-ray is a projection radiograph of the chest used to diagnose conditions affecting the chest, its contents and nearby structures. Chest radiographs are the most common film taken in medicine. This classifier will precisely predict the difference between the positive cases and the negative cases. In this article, we have used data that is available from open sources and some from the hospitals. This model building involved distributing the dataset by using pre-processing tools and then creating a neural network.

II. RELATED WORK

Deep learning in health care is used to assist professionals in the field of medical sciences, lab technicians and researchers that belong to the health care industry. Deep learning in health care helps to provide the doctors, the analysis of disease and guide them in treating a particular disease in a better way. So, the medical decisions made by the doctors can be made more wisely and are improving in standards.There are a few techniques involved in the medical industry such as CT scan, ECG, and MRI etc. that are used to diagnose harmful diseases. The harmful diseases include brain tumour, heart attacks, cancer, and many others. Hence, deep learning can be used to consult doctors who analyse the patient's disease and provide them with good treatment. Recent studies have also showed that medical images help in improving the analysis of the presence of viruses in the lungs.

In a work done by [1], a Deep Convolutional Neural Network-based solution is applied; where it can detect the COVID-19 positive patients used chest X-ray images. They have used multiple CNN models such as DenseNet201, Resnet50V2 for implementing this work. These models are then combines to predict a class value. Moreover, they have also used publicly available dataset where there were 538 images of COVID positive patients and 468 images of COVID negative ones. Their classifier gave an accuracy of 91.62%. They have also developed a GUI based application for public use.

Also, an article published by [], where a Deep Learning model is used for detection and classification of COVID-19 patients. In this work, models used were MobileNetV2, Resnet50, InceptionV3, NASNETMobile, VGG16, Xception. These models have been used to carry out tasks on two different datasets. Dataset 1 included the images with classes: Normal, COVID, Pneumonia and Dataset2 included: the same classes with more focus on two categories of pneumonia: bacterial pneumonia and viral pneumonia.

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III. PROPOSED APPROACH

The proposed solution is based on COVID 19 and normal cases. It is also tested on unseen classes to validate a regularization of the constructed model. They include other normal cases where chest X-ray images are normal without any disease but with some small remarks, and other abnormal cases where chest X-rat images are abnormal with some other diseases such as COVID 19.

For the experimental setup, the size of the images has been scaled to 224×224 pixels. Before providing training to the CNN model, the contrast of the images has also been improved by using clipped adaptive histogram equalization. Contrast improvement and noise removal from the images has led to a better model.

The primary goal of this work is to build a deep learning model for the accurate and early detection of COVID-19 disease using chest X-rays. The first dataset contains three classes (Normal, COVID, and Pneumonia), and the second one consists of four categories (Normal, COVID, Bacterial Pneumonia, and Viral Pneumonia). In the sub-sections below, each block in Figure 1 is addressed in detail.

We then classify the images belonging to different categories. Also, a pre-trained transfer learning model has been used, which have been fine-tuned for the specific layers. We use filter concatenation for a deeper classification and accuracy of the X-ray image. So, we use this because the number of distinct patterns you can see will be less at the lower layers and if you go deeper into the neural network, we have a higher receptive field. A clear and concise understanding of this is given in the figure below Image.1 [1].

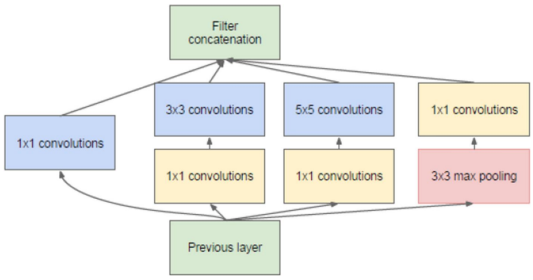

Image 1. Block Diagram for Filter Concatenation

In the testing phase, the trained model is applied on each resized chest X-ray image, to compute its class and accuracy.

IV. DATASET

A. Gathering the Dataset

The images have been taken from various online resources and are classified into different types. The images are of Pneumonia, COVID and normal images. Also, the metadata of the images collected have different type of attributes. The attributes are given in Table 1. The goal during this process was to maintain the quality of the images.

Attributes	*Description*
Patient ID	Id dedicated to the patient
Offset	Number of days since the start of the symptoms
Sex	Male, Female
Age	Age of the patient in years
Finding	Type of Disease
Survival	Yes (Y) or No (N)
View	(PA) Poster anterior, Antero Posterior (AP), AP Supine (APS)
Modality	CT, X-ray
Date	Date on which the image was acquired

Table 1. Shows the attributes of the metadata

For this work, the data contains CXR images of different patients from which only the frontal images are considered and lateral images are discarded. This is because the lungs can be better examined from the frontal view rather than the lateral one. The dataset of CXR images are labelled as COVID-19, Pneumonia and Normal as mentioned earlier. But, for this research work, we are going to segregate the data into two categories- COVID-19 positive (class 0) and COVID-19 negative i.e. normal (class 1). For Class 0 there are a total of 196 images which can be seen in Image 2 and there are 196 images for Class 1 (negative cases) as shown in Image 3.

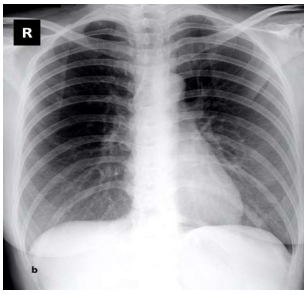

Image 2. Class 0 image

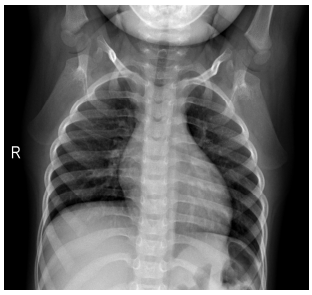

Image 3. Class 1 image

B. Pre-processing the Dataset

The images are first resized into 224 X 224 shaped images. The original sizes of the images are from 1974 X 1306. Before providing the training to the CNN model, we have first segregated the datasets into two folders. After this we start feeding the data into the model.

V. METHODOLOGY

For selecting the model, the Sequential Model for CNN was the best because it was easier for the implementation and we can get accurate predictions and classifications as well.

A sequential model is appropriate for a plain stack of layers where each layer has exactly one input tensor and one output tensor. We used four layers for an accurate prediction.

Conv2D layer for true outputs would be the best option for classification. This layer creates a convolution kernel that is convolved with the layer input to produce a tensor of outputs. When using this layer as the first layer in a model, provide the keyword argument input shape. Moreover, 4 layers have been created for the prediction. Multiple filtering at each level gives a stable and uniform data. A convolutional layer with 32 filters has been created. After creating the model with different layers we get this output. Given in the Image below.

```
Model: "sequential_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_4 (Conv2D)            (None, 222, 222, 32)      896
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 220, 220, 64)      18496
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 110, 110, 64)      0
_________________________________________________________________
dropout_4 (Dropout)          (None, 110, 110, 64)      0
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 108, 108, 64)      36928
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 54, 54, 64)        0
_________________________________________________________________
dropout_5 (Dropout)          (None, 54, 54, 64)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 52, 52, 128)       73856
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 26, 26, 128)       0
_________________________________________________________________
dropout_6 (Dropout)          (None, 26, 26, 128)       0
_________________________________________________________________
flatten_1 (Flatten)          (None, 86528)             0
_________________________________________________________________
dense_2 (Dense)              (None, 64)                5537856
_________________________________________________________________
dropout_7 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_3 (Dense)              (None, 1)                 65
=================================================================
Total params: 5,668,097
Trainable params: 5,668,097
Non-trainable params: 0
```

Image 4. Sequential Model Summary

A. Training

Transfer learning is the method of taking the weights of a pre- trained model and using the previously learned features to make a decision of a new class label. A network is used in transfer learning that is pre-trained in the image-net dataset, and this network learnt to identify high-level features of images in the initial layers.

We use the fit generator method for the execution of our model. The fit generator function in Python is two separate deep learning libraries which can be used to train machine learning and deep learning models.

B. Tools Used

I used Google Colab, Python 3.8 and Tensor Flow 2.2.0. For the implementation of CNN, I used the deep learning library from Tensor Flow. The pre-processing and segregation of dataset was done in Jupyter Notebooks. Also, the implementation and working was done on the Google Colab platform.

C. Performance Metrics

To evaluate the performance of the proposed approach, the metrics adopted are classification accuracy, sensitivity, F-1 score and recall are measured as follows:-

$$\text{Classification Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

$$\text{Sensitivity} = \frac{TP}{TP + FN}$$

$$\text{F-1 Score} = \frac{2 \times \text{sensitivity} \times \text{Precision}}{\text{Sensitivity} + \text{Precision}}$$

$$\text{Recall} = \frac{TP}{TP + FN}$$

Here, TP stands for True Positive, FP for False Positive, FN for False Negative and TN for True Negative. In a confusion matrix, the COVID-19 positive cases that are correctly classified by the model are termed as True Positive and incorrectly classified as COVID negative are termed as False Positive. Similarly, COVID negative subjects classified correctly are termed as True Negative and incorrectly classified as COVID positive are termed as False Negative.

VI. RESULTS

After evaluating the model with some parameters we got an accuracy of 97.10 %. With the extracted feature, one ML classifier was trained. The fine-tuned hyper parameters are generated for a better understanding. To evaluate the model, several performance metrics were considered for the efficient diagnosis of COVID-19. In this test set a total of 196 COVID-19 positive images and 196 normal X-ray images were taken. In the confusion matrix, the actual cases were placed along rows, and predicted cases were placed along columns. For CNN, among 196 COVID-19 cases, the model accurately predicted the exact class label of COVID-19 images and misclassified 10 as normal. A confusion matrix was created where we could a better understanding of all the Classification Accuracy parameters. The given image below shows us that our model has accurately predicted the True positives (TP) and True Negatives (TN).

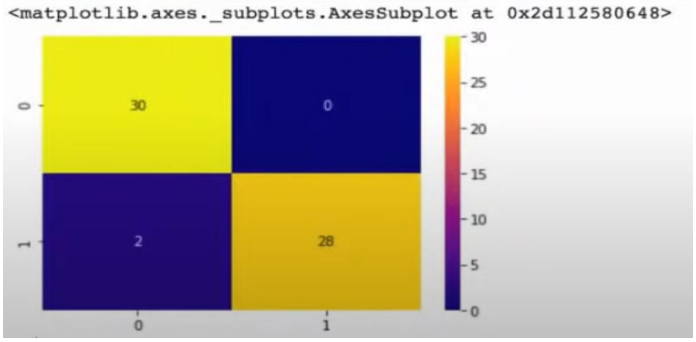

Figure 5. Confusion Matrix for the Sequential Model

The CNN model which was used gave a class accuracy of 97.1%. The precision calculated for 100%. The recall for the model was 96.52%. Also, lastly, the F-1 score was a total of 98.23%

A confusion matrix gives you an overall prediction. This confusion matrix is based on the test data that we have generated using the CNN model. The square to the top left is True Positive, which means the patients that are having the COVID-19 virus. The square to the top right is called False Negative, that is patients that are classified wrongly classified as COVID-19 negative but in actuality are positive. The square to the bottom right represents True Negative that means patients that are normal and have no COVID are classified correctly as normal. Lastly, the square to the bottom left is False Negative which means, the cases that are wrongly classified as COVID positive but are actually normal that is COVID negative.

VII. CONCLUSION

With the increasing number of COVID patients every day and the contagious nature of COVID-19, the number of cases will increase more, if the accurate and timely diagnosis of the patient is not made, then it would affect other people. Hence, an automated diagnosis technique is required for the timely detection and diagnosis of COVID-19 as Neural Networks have paved their way into this world.

The results obtained in this study are limited due to smaller datasets available for the training of the deep learning models. Furthermore, the proposed models need to be validated on external datasets to get better results. In future work, more image data can be incorporated to get better results.

Fast and timely detection of COVID positive patients is necessary to avoid spreading the disease and keeping it in control. This research work has been done to detect the COVID positive patients from Chest X-Ray images in a simple and inexpensive way. In the work proposed in this paper, three state-of-the-art deep learning models have been adopted and ensemble. The proposed model has achieved a classification accuracy of 91.62%.

Even more important fact is it yields a sensitivity of around 95% for COVID positive cases i.e., out of 100 COVID positive patients, more than 95 can be correctly diagnosed by our proposed model.

The proposed solution offers an accurate model which has a total of 97% accuracy and this can be used in real time detection. The spread of COVID has become prolific and due to this medical researchers need to classify the X-rays very efficiently. This model could help mitigate this demerit.

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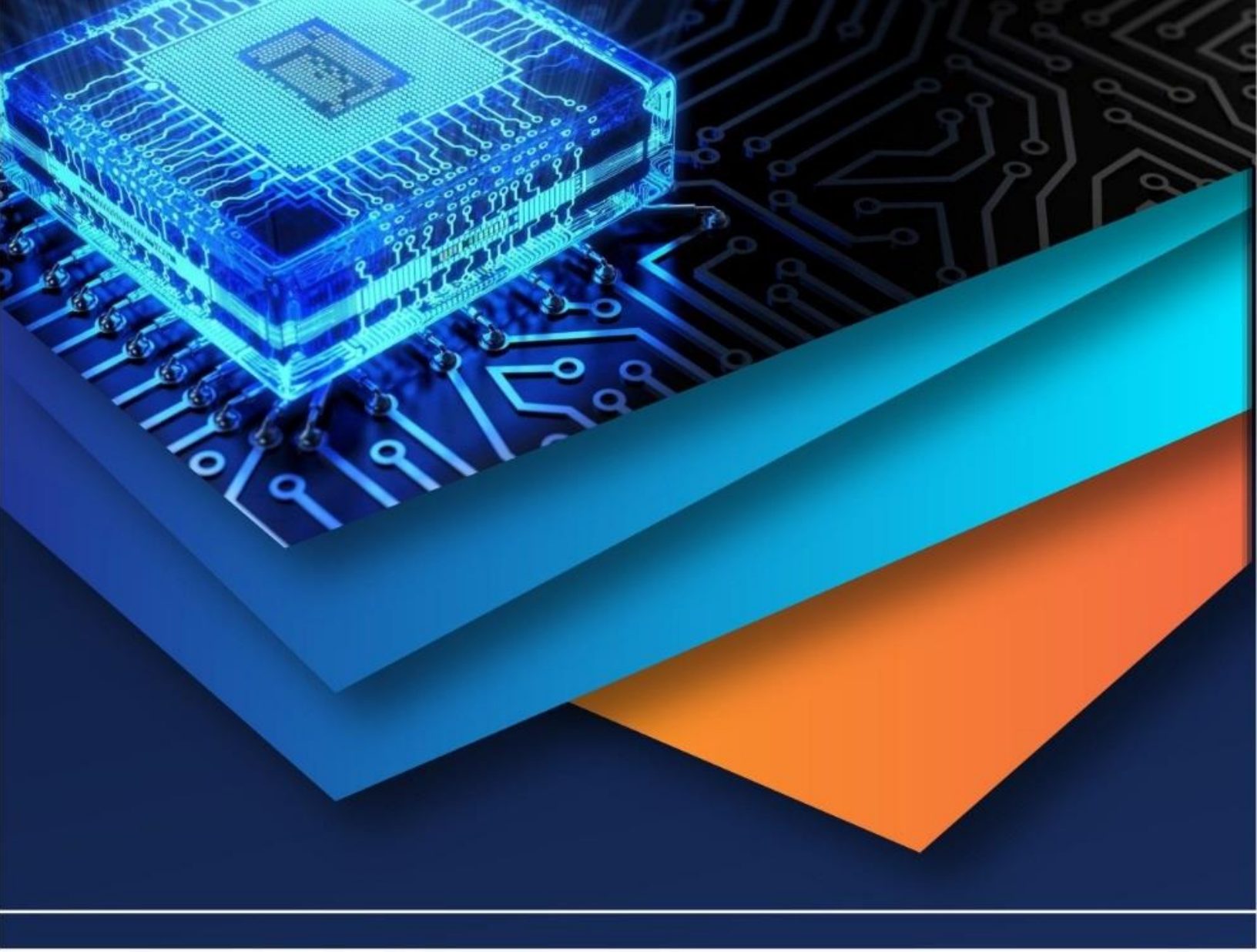

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