3D CNN Model for The Diagnosis of COVID-19 By Classification of Chest CT scans

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Abstract- This paper will discuss the steps that are needed to build a 3D convolutional neural network (CNN) to predict the presence of viral pneumonia in Computer Tomography (CT) scans. 2D CNNs are commonly used to process RGB images (which have 3 channels). A 3D CNN is simply the 3D equivalent of 2D CNN. It takes a 3D volume or a sequence of 2D frames (e.g., slices in a CT scan) as input. To implement this project, we use a subset of the MosMedData: Chest CT scans with COVID-19 Related Findings, which consists of CT scans of the lungs with COVID-19 related findings and without such findings. We will be using the associated radiological findings of the CT scans as labels to build a classifier to predict the presence of viral pneumonia. Hence, the task is a binary classification problem.

Indexed Terms- Convolutional Neural Network (CNN), COVID-19, CT scan, Viral Pneumonia.

I. INTRODUCTION

Viral pneumonia, as the name implies, is pneumonia caused by a virus. In general. Pneumonia may be caused by either bacteria (mostly seen in adults), fungi, or viruses (in children). The major damage to a person suffering from viral pneumonia occurs to his or her lungs, where the pulmonary alveoli get inflamed with pus. The most common causes of viral pneumonia are *Influenza Virus* A and B, *Respiratory Syncytial Virus* (RSV), *Human parainfluenza viruses* (in children), *severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).*

The first place in which the coronavirus has been sighted is Wuhan, China [1]. Also popularly known as viral pneumonia, coronavirus is categorized as COVID-19, SARS, and MERS. In the past year, the world has been battling this pandemic due to the coronavirus, for which the standard vaccine is yet to be invented. Still, the number of cases has been increasing due to the spread of the virus just by a simple touch. And, recent reports claim that the better option for protecting ourselves is to do more tests and isolate the people who are diagnosed with COVID-19.

Computed tomography (CT) scans and X-ray images are some of the methods used in detecting the coronavirus. Doctors and radiologists examine the said CT scans and X-rays and look for any abnormalities in the lungs that might be caused due to the virus. In such cases, the doctors may not be able to provide the diagnosis at the right time due to a heavy schedule and their allocated working hours, which may delay the results. Delays made in detecting the virus may lead to higher inflammation in the lungs or spreading to other people if not taken proper care of. CNNs include Alex Net [3], Google Net [4], VGG [5], Mobile NetV2 [6], Res Net [7] and Dense Net [8].

The proposed deep learning model mainly focuses on the accuracy of the test report and the speed with which the result is obtained. It helps radiologists and assists them in determining whether a person is tested positive or negative to COVID-19.

II. EXISTING METHODS

Reverse transcription-polymerase chain reaction test (RT PCR)

A polymerase chain reaction (PCR) test [9], is a test that is used to detect the presence of a virus if you are infected with one at the time of the test and also fragments of the virus if you have had any viral infections in the past. This test is mainly performed to detect the genetic presence of said virus in our bodies. The steps in the COVID-19 PCR test are i Sample Collection - A swab of respiratory material from nose or cheek cells in the mouth is collected as a sample.

Fig. 2.1 A nasopharyngeal swab for COVID-19 testing

ii. Extraction - The process of separating genetic material from the sample, which may consist of the virus's genetic material.

iii. PCR - A PCR machine, called a thermal cycler, along with several other chemicals present in it, causes a reaction to occur that makes millions of copies of a small portion of the genetic material of SARS-CoV-2. Fluorescent light is produced by the PCR, indicating the presence of the coronavirus, which is picked up by software to give the test result as positive. If the fluorescent light did not appear, then the report is given as negative.

Fig. 2.2 PCR Machine

B. Antigen test

This test takes less time when compared to the PCR test but it is not as accurate as of the PCR test. It detects the proteins, called "Antigens", on the surface of the virus. It is easy for us to detect the presence of the virus when a rapid antigen test is performed at the earlier stages of diagnosis with utmost accuracy as the number of virus cells is more in the early stages.

C. Computed Tomography

Computed Tomography or CT scans are the computerized x-ray images that are obtained by directing a narrow beam of x-rays onto the patient's body in every direction with the help of rotation, thus producing a series of images called "slices" of the internal organs of the patient. These slices when stacked together form a 3D view of the internal tissues and organs, which helps in easier identification of the abnormalities or basic structures of that particular tissue or organ. Chest CT scan images in patients diagnosed with COVID-19 associated viral pneumonia usually show Ground-Glass Opacification (GGO), Halo signs, and the development of cavities in lung lesions. Some studies have reported that the abnormalities in chest CT scans are usually bilateral, involving the lower lobes, and have a peripheral distribution.[10],[11].

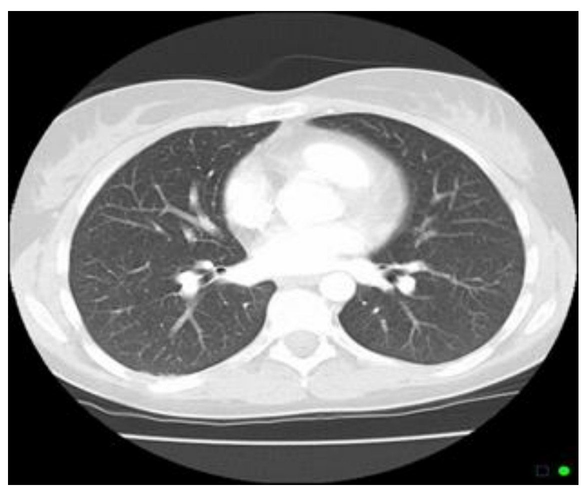

Fig. 2.3 Normal Chest CT scan

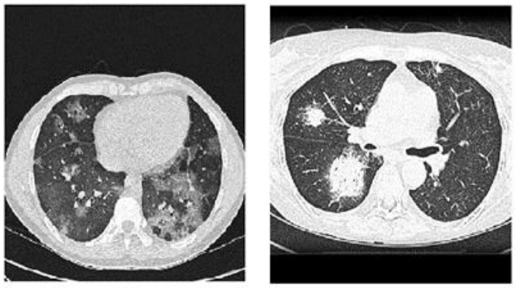

Fig. 2.4 Abnormal chest CT scans with GGO and Halo sign

As discussed earlier, a person's CT scan consists of several CT images which makes it a heavy task for the radiologists to diagnose accurately and in less time. So, a deep learning model is proposed to accurately give the result of the presence of viral pneumonia in a short time.

III. PROPOSED METHOD

The proposed method uses 3D Convolutional Neural Networks (CNNs) for the classification of CT scans. In general, 3D CNNs have the architecture as follows.

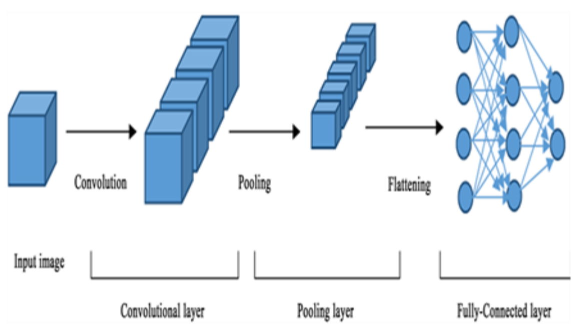

Fig. 3.1 Architecture of 3D CNN

The layers in the above architecture are described below.

A. Convolution layer - It is the building block of a CNN. It performs 3D convolution, which can be simply specified as the application of a filter to the input image. It helps in extracting the features of the input image thus summarizing the detected features of that image.
B. Pooling layer - It helps in reducing the size of the image. There are 3 types of pooling techniques that can be used in this layer. Max Pooling, Min Pooling, and Average Pooling, which result in maximum value, minimum value, and the average value of the pixels present in the image respectively.
C. Fully-Connected layer - This is the last layer in the architecture of CNN, which takes the output of the convolution or the pooling layers after flattening, as its input. This is the layer where all the outputs of the previous layers are connected to every activation unit in the next layer, which helps in compiling all the data from the previous layers to form the output.

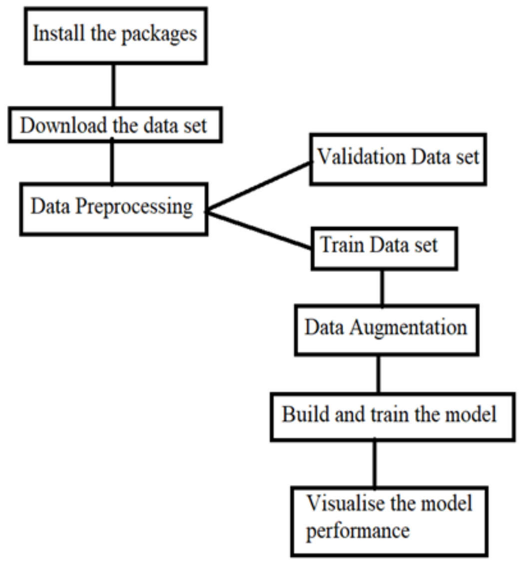

Fig. 3.2 Proposed Methodology

The proposed methodology, shown above includes at first, the required packages are to be installed or set up for future use of the model. Then, the data set is to be downloaded. In this case, the data set is a subset of MosMedData*: Chest CT scans with COVID-19 Related Findings.*

After downloading the data, it is to be pre-processed i.e., with a fixed orientation with the help of rotation. Pre-processing the data makes it uniform so that the machine understands it easily. The processed data is then split into valid and training data sets for validating the final result and training the data to identify the abnormalities in the image. The data that is to be trained is augmented using a random rotation process to increase the number of possibilities for an image to occur. A 3D CNN is built so that the train data set is to train the constructed model. This model consists of the same layers like that of a general 3D CNN architecture as described previously. The augmented data is used to train the model to improve the accuracy for detecting abnormal CT scans.

IV. RESULTS AND DISCUSSION

The augmented data is plotted using Matlab which is shown below.

```
Dimension of the CT scan is: (128, 128, 64, 1)
<matplotlib.image.AxesImage at 0x7f13d054c650>
```

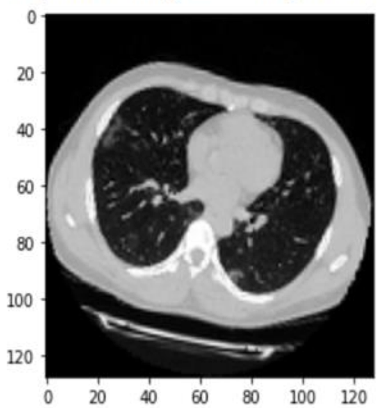

Fig. 4.1 Visualisation of Augmented CT scan

We are using 100 epochs to train the data, in which the model is trained and validated at the end of each epoch as shown below. This ensures the accuracy of the model in predicting the presence of viral pneumonia. When a single CT scan is taken, the model achieves an accuracy of 80 to 90% in predicting the result.

```
Epoch 48/100
70/70 - 23s - loss: 0.2472 - acc: 0.9143 - val_loss: 0.7466 - val_acc: 0.7500
Epoch 49/100
70/70 - 23s - loss: 0.1733 - acc: 0.9571 - val_loss: 0.8760 - val_acc: 0.7000
Epoch 50/100
70/70 - 23s - loss: 0.2145 - acc: 0.9214 - val_loss: 0.9878 - val_acc: 0.6500
Epoch 51/100
70/70 - 23s - loss: 0.1931 - acc: 0.9500 - val_loss: 1.0363 - val_acc: 0.7000
Epoch 52/100
70/70 - 23s - loss: 0.2837 - acc: 0.8714 - val_loss: 1.3566 - val_acc: 0.6500
Epoch 53/100
70/70 - 23s - loss: 0.1881 - acc: 0.9571 - val_loss: 0.9198 - val_acc: 0.7500
Epoch 54/100
70/70 - 23s - loss: 0.2108 - acc: 0.9214 - val_loss: 0.5645 - val_acc: 0.8167
```

Fig. 4.2 Training and validating the model at the end of each epoch

As we are using a subset of a complete data set the efficiency of the model reaches up to 83%. But, when the full data set is used, a variation of 6 to 7% can be seen in the performance of the model.

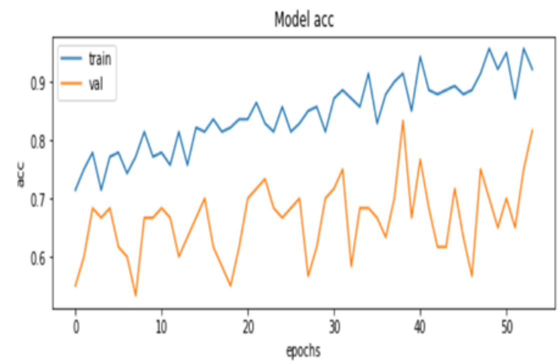

Fig. 4.3 Visualisation of Model Accuracy

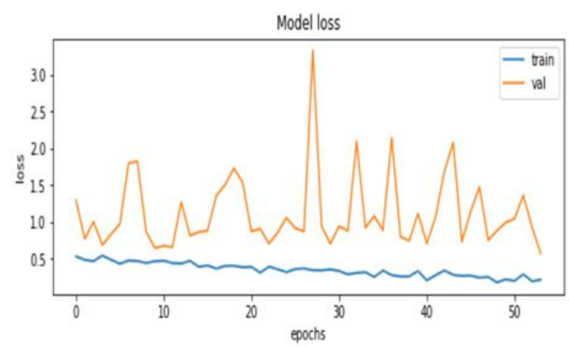

Fig. 4.3 Visualisation of Model loss

```
This model is 13.03 percent confident that CT scan is normal
This model is 86.97 percent confident that CT scan is abnormal
```

Fig. 4.4 Prediction on a single CT scan

CONCLUSION

A 3D Convolutional Neural Network is built and trained to predict the presence of viral pneumonia using the dataset containing samples of normal and abnormal chest CT scans. This model assists the radiologists to diagnose easily and with utmost accuracy to be given proper medication in a specified time. It can also be used to detect other diseases like cancers in the human body. So, we can further extend this project by adding the datasets related to the diseases like lung cancers, breast cancers, etc., and training the model for those datasets. This helps in the recognition of harmful abnormalities and their treatment, in turn saving many lives.

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