COVID-19 detection from chest X-ray images using Convolutional Neural Networks

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Govind B Chandran

Abstract

The COVID-19 pandemic which started in late 2019 has brought a lot of negative impacts on the world and continues to have catastrophic effects on the lives of human beings throughout the world. To combat this virus, it is necessary to screen the affected patients in a fast and inexpensive way. One of the most viable steps towards achieving this goal is through radiological examination, Chest X-Rays (CXR) being the most easily available and least expensive option. Hence, a deep convolutional neural network-based solution which can detect the COVID-19 positive patients using chest X-Ray images is amongst the best ways. The effectiveness of artificial intelligence (AI) in the rapid and precise identification of COVID-19 from CXR images has been explored based on different pre-trained deep learning algorithms and fine-tuned to maximise detection accuracy to identify the best algorithms. The results showed that deep learning with X-ray imaging is useful in collecting critical biological markers associated with COVID-19 infections. Models can be evaluated using different criteria. This report is aimed at scrutinizing the effectiveness of the Convolutional Neural Networks (CNNs) on the automatic diagnosis of COVID-19 from chest X-rays.

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Chapter 1

Introduction

The COVID-19 pandemic has affected the world extensively in the past 2 years. Millions of lives were lost, lock-downs were imposed, a lot of people lost their jobs and were struggling to make ends meet. The focus here will be on the amount of lives that were taken during the pandemic by the corona virus infection.

After a person has caught the infection, the best way to get cured is to detect that you have caught the infection early. The earlier you detect it, the better your chances are of getting cured soon. But the dramatic increase in the amount of infected people grew exponentially which resulted in the shortage of laboratory testing kits.

This is when radiological examinations mainly CT scans or Computed Tomography scans became popular. But taking CT scans for a huge amount of patients and examining it became a burdensome process for the doctors. Hence a faster and easier way of taking Chest X-Ray images became the go-to method.

But the problem here was that the Chest X-Ray images of the corona infected patients and the Pneumonia looked extremely similar. Hence, a human cannot give accurate predictions just by looking at the X-Ray scans. Hence artificial intelligence helps to give proper and accurate diagnosis.

So the power of image processing and deep learning is used to build such artificially

intelligent systems that can help for accurate classifications. Hence, the Convolutional Neural Networks is used for this task which by far is one of the most powerful ways of processing images and giving accurate results.

The report is organized as follows: Chapter 1 gives an introduction to the seminar including the basics of the topics in the report. Chapter 2 contains the literature survey done as part of the seminar preparation. Chapter 3 describes about the methodology of the method discussed in the seminar. Chapter 4 contains the explanation of Convolutional Neural Networks which is important to know to understand the topic. Chapter 5 contains the performance evaluation of the topic in the seminar. Chapter 6 contains the conclusion of the topic

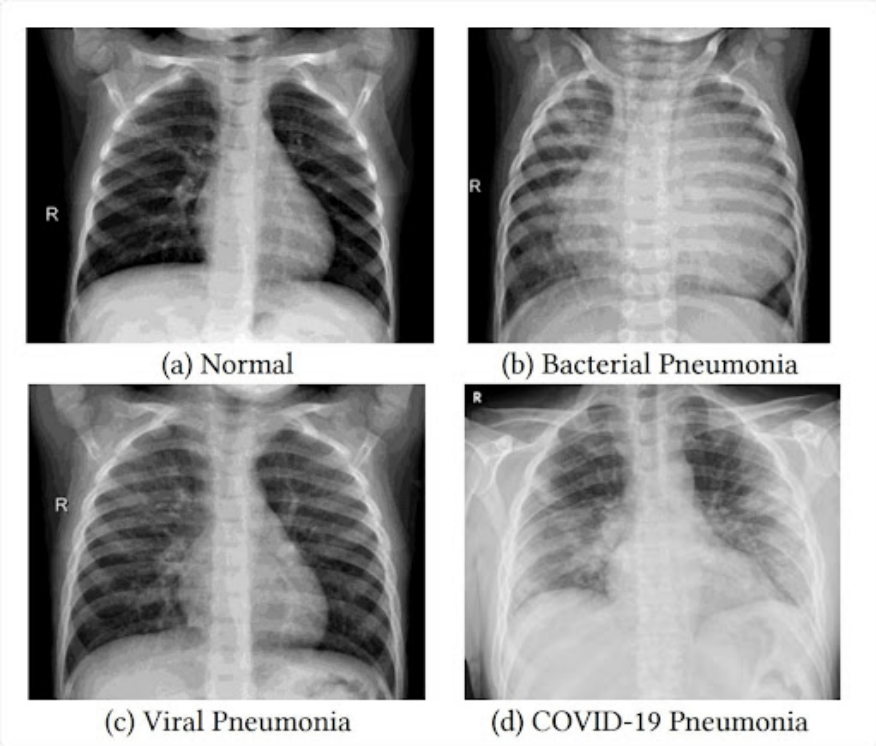


Figure 1.1: Comparison of Chest X-Ray images

Chapter 2

Literature Review

There were several techniques before to predict whether a person had been infected by the corona virus, but all of those methods had their own faults or disadvantages. When examining or diagnosing a patient, taking risks cannot be afforded, so its important to discard methods which are unreliable. Given below are some of those techniques and their descriptions.

2.1 Symptom Analysis

In the early days of the virus/disease, there was no particular way in order to identify whether an individual was infected or not. Then people started seeing symptoms like fever, breathlessness, headache, dry cough and in few cases, loss in smell and taste in the infected people. But since these were symptoms were similar to that of the common cold too, this kind of diagnosis was not reliable. **Advantages:** Fast and easy method. **Disadvantages:** Highly inaccurate and unverifiable results.

2.2 Reverse Transcription Polymerase Chain Reaction

The RT-PCR method is where the testing agent collects mucus or saliva samples from the patient using ear swabs. These samples are the sent to laboratories for testing using molecular testing methods. **Advantages:** Highly accurate results. **Disadvantages:** Highly time consuming which can be fatal.

2.3 CT Scans

The Computed Tomography [CT] scans are scans where the images of bones, soft tissues, blood vessels all appear at the same time with a high resolution. This was able to detect things like brain tumour, cancer, liver diseases, and even the corona infection. **Advantages:** High accuracy and fast detection. **Disadvantages:** Highly burdensome and time consuming for taking the scans.

Chapter 3

Methodology

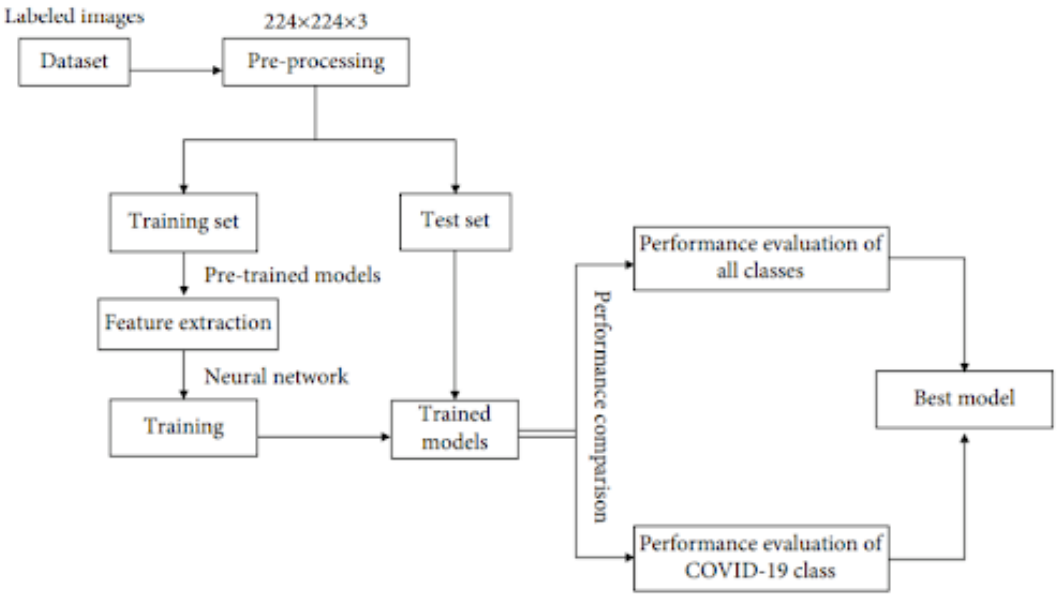


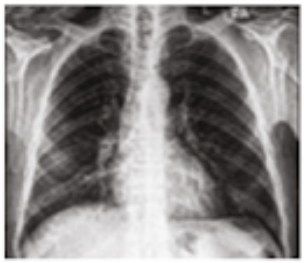
Figure 3.1: Block Diagram of the method

3.1 Dataset and Image Preprocessing

The dataset here is images of chest X-ray scans of 3 types of classes. 1. Healthy 2. COVID-19 infected 3. Pneumonia infected. As discussed earlier, the case of pneumonia is taken too because of how similar it's chest X-Ray scans looks when compared

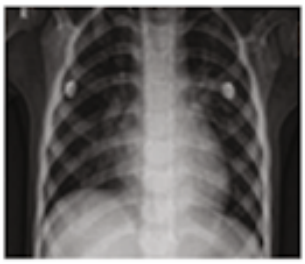
to the COVID-19 infected one. These images or the entire data-set is verified by chest specialists or doctors. All these images are of the format PNG [Portable Network Graphics] because of its high resolution. The images are of 1024x1024 pixels. These images are then resized, trimmed accordingly as per the pre-trained model standards for obtaining high accuracy. This dataset after preprocessing is split into training set and testing set, which is normally of the ratio 8:2.

Data	COVID-19	Healthy	Viral pneumonia	Total images
Train	820	1140	1150	3575
Test	82	114	115	311



(a) COVID-19

(b) Healthy



(c) Viral pneumonia

Figure 3.2: Summarised dataset for training and testing

3.2 Pretrained models and Transfer learning

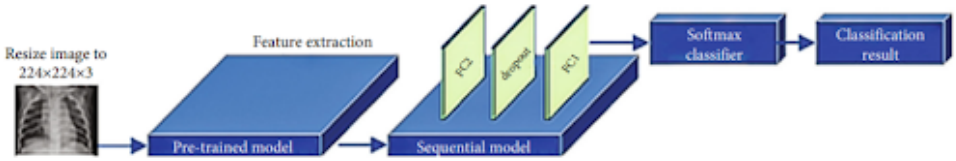


Figure 3.3: Outline of the system

The pre-trained models used here are MobileNet, VGG16. Pre-trained models are just models which were trained earlier for some other purpose, but is reusable for this purpose to build a neural network easily and obtain higher accuracy. MobileNet is a type of Convolutional Neural Network which has 51 layers and was used in mobile and embedded vision applications. VGG16 is also a type of Convolutional Neural Network which has 16 layers of neurons.This model when tested against the ImageNet dataset produced an accuracy of 92.8 percent and was able to classifiy over 1000 objects correctly.

Transfer learning is being used here to obtain good accuracy using the pre-trained models. Transfer Learning is an ML [Machine Learning] method where the model developed for a task is used as the starting point in another task. Pre-trained models are used for feature extraction. Feature extraction is the process of removing redundant data from the images. Redundant data of an image is the portion or part of the image which does not convey any useful imformation to the neural network and hence does not help with the classification of images. Doing feature extraction makes the neural network more accurate.

The sequential model consists of a sequential layer and a model built on top of it. The sequential layer is just a foundation on top of the neural network for the current task can be built upon. A fully connected neural network is where all the neurons of a layer is connected to all other neurons of the next layer, The dropout layer is a layer

which is used to prevent overfitting in the neural network. Overfitting is the process of using a lot of training data for training but since a lot of noise and unwanted data gets in, reduces the total accuracy of the neural network.

The Softmax classifier is a mathematical function that converts a vector of numbers into a vector of probabilities. The sequential layer gives the output as a vector of numbers and this for a human can be hard to analyse and would take a lot of time. Hence the conversion of a vector of numbers to that of probabilities help visualise which class has the highest chances that image would be.

Chapter 4

Convolutional Neural Networks

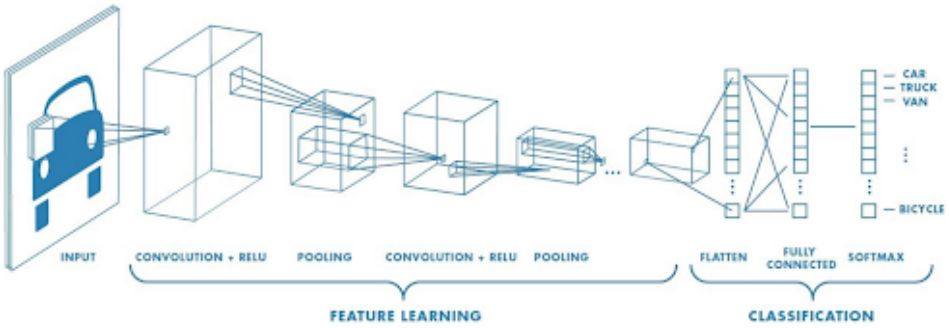


Figure 4.1: Architecture of CNN

Convolutional Neural Networks [CNN] is the neural network being used here. It is an artificial neural network used in image recognition and processing specifically designed to process pixel data. CNN reduces the images to a form which is easier to process, resulting in a higher accuracy while testing. CNN has multiple layers of Convolutional layer and Pooling layer which is used for training and feature extraction purposes.

The convolution layer is a feature extraction layer which extracts the important features from the image that has been passed into it. It uses an activation function called ReLU [Rectified Linear Unit] which reduces the computation time in the neural network.

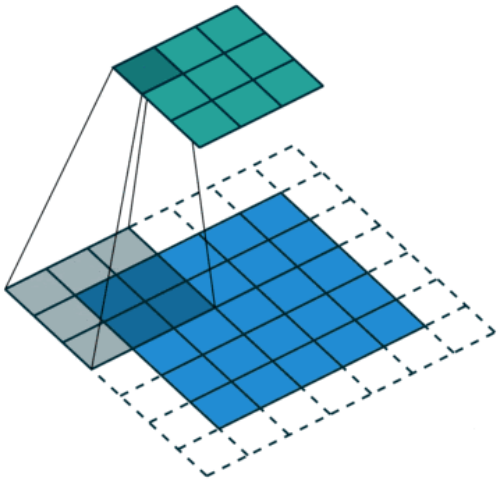


Figure 4.2: Convolutional Layer

The pooling layer is a layer which reduces the dimensions of the feature maps produced by the convolutional layer which helps in reducing the computational time and complexity of training the network. It uses algorithms like average pooling and max pooling to do pooling.

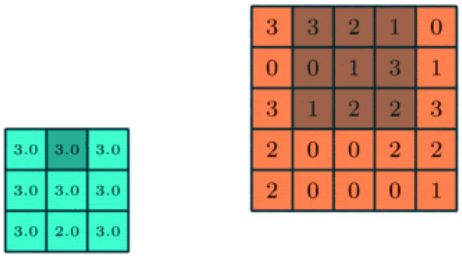


Figure 4.3: Pooling Layer

The flatten layer converts the multidimensional array of pixel data produced by the feature learning layer into a single array of pixel data for transferring it to the neurons in the next layer efficiently. The fully connected neural network classifies the given image properly and the softmax classifier outputs a set of probabilities signifying which class the input image was.

Chapter 5

Performance Evaluation

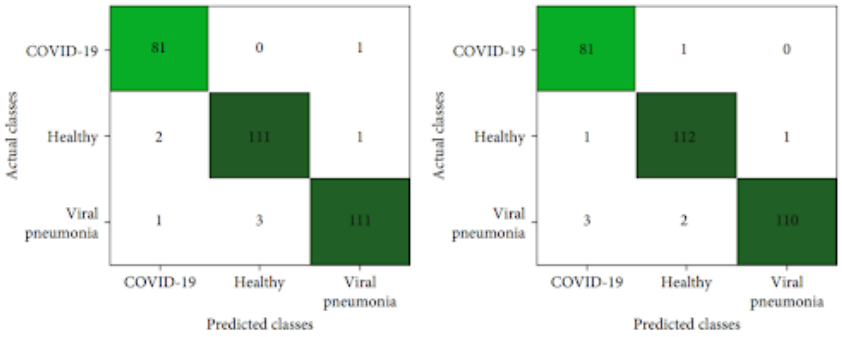


Figure 5.1: Confusion matrices of a) VGG16 b) MobileNet

The confusion matrix is a certain matrix used for visualising and evaluating the accuracy and other performance matrices of the CNN. It has 4 main components. 1. True Positive, which is the amount of accurately classified images of COVID-19 infected chest X-ray images. 2. True Negative, which is the amount of accurately classified images of healthy and pneumonia infected chest X-ray images. 3. False Positive, the amount of images that were incorrectly predicted as COVID-19 infected. 4. False Negative, the amount of images that were incorrectly classified as COVID-19 negative, or not classified as COVID-19 positive.

In the above image it is seen that the true positive and true negative values are given in the green boxes. The rest are false positive and false negative.

The main performance matrices are 1. Accuracy 2. F1 Score 3. Precision 4. Sensitivity 5. Specificity

Accuracy is the measure of the amount of images that were accurately classified off all the predictions the neural network has made.

F1 score is the measure of the amount of images that were incorrectly classified off all the predictions the neural network has made.

Precision is the amount of times a particular images was correctly classified by the neural network off the total amount of times that image was passed.

Sensitivity is the ability of a neural network to designate a person as COVID-19 positive.

Specificity is the ability of a neural network to designate a person as COVID-19 negative.

$$\text{Accuracy}(\text{Acc})_i = \frac{\text{TP}_i + \text{TN}_i}{\text{TP}_i + \text{FP}_i + \text{TN}_i + \text{FN}_i},$$

$$F1\ \text{score}_i = 2 \times \frac{\text{PPV}_i \times \text{Sen}_i}{\text{PPV}_i + \text{Sen}_i},$$

$$\text{Precision}(\text{PPV})_i = \frac{\text{TP}_i}{\text{TP}_i + \text{FP}_i},$$

$$\text{Specificity}(\text{Spc})_i = \frac{\text{TN}_i}{\text{FP}_i + \text{TN}_i},$$

$$\text{Sensitivity}(\text{Sen})_i = \frac{\text{TP}_i}{\text{TP}_i + \text{FN}_i},$$

Figure 5.2: Performance metrics used to evaluate CNN

Chapter 6

Conclusion

The pretrained models used here are VGG16 and MobileNet. The higher accuracy was given by VGG16 with 98.71 percent while MobileNeet gave an accuracy of 98.3 percent. We can undertsand that deep learning with X-ray Imaging cab extract a lot of significant biological markers related to COVID-19 disease which can be highly useful for creating other models. We can still achieve higher accuracies with deep learning.

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