Detection of COVID-19 Using Chest Radiographs with Intelligent Deployment Architecture

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Abstract The outbreak of Coronavirus Disease (COVID-19) has caused a huge disturbance globally. The problem is the unavailability of vaccines and limited resources for its detection. In this paper, authors have carried out a case study of India to analyse the problem faced by the authorities for detecting COVID-19 amongst the suspected cases and have tried to solve the problem using a Deep Neural Network-based approach for analyzing chest x-rays in order to detect the onset/presence of related disease. After obtaining data from available resources, we trained a transfer learning-based CNN model. The model tries to extract the features of the radiographs and thus classifies it into the appropriate class. Heat map filter was used on the images significantly helping the model to perform better. This paper presents the validation of the model on certain test images and shows that the model is reliable to an extent. This paper also demonstrates a general architecture for the deployment of the model as per the considered case study.

Keywords Deep learning · Radiography · Feature extraction · COVID-19 · Heatmap filter · CNN

1 Introduction

Recently, the outbreak of Coronavirus Disease (COVID-19) proved to be disastrous due to the exponentially increasing number of cases worldwide. Not only the confirmed cases are increasing but also the number of deaths across the world seems to increase exponentially. As of early April 2020, around 1.34 million cases have been
confirmed affected by COVID-19. Out of which 74,782 have been reported dead. There’s no vaccine present currently for this virus/disease. One of the major problems associated with this is complexity in the detection of the disease. The symptoms of this disease are cough, cold, and headache. Differentiating this common flu-like symptom with the existence of Coronavirus is difficult. Moreover, as of April 2020, not enough medical facilities are available to conduct tests in order to detect disease on a wider population. The tests which are available are mostly restricted to developed and urban residences. The following case study of India demonstrates the problem in details.

Case Study: Problem Scenario in India

India stands as at the second position in terms of population in the world. Keeping in mind the population of 1.35 billion, the healthcare facilities are not capable enough to deal with a pandemic situation. The number of cases being detected strongly depends upon the number of people being tested or screened. But in India, the testing is only done for people who came from some foreign nations in a period of a month or the ones who have been in contact with them. This makes it difficult to analyze the community spread in the country with a massive population and density [1, 2]. As per the Indian Council of Medical Research (ICMR), until 24th March 2019, only 18 tests were done per million of the population. Whereas countries like Italy got a greater number of confirmed cases because they had conducted around 5000 tests per million of the population until the same time [3]. Figure 1 depicts the number of tests conducted per million of the population by different countries of the world as per the ICMR reports [4].

Recently India imported certain rapid testing kit from China in order to detect COVID-19 amongst the suspects easily. Unfortunately, ICMR had to impose a halt
on these kits due to the high variation found in the results on 21st April 2020. As per the health ministry of the state of Rajasthan, India, the kits gave an accuracy of only 5.4% [5]. Not only India, but the inaccuracy with the performance of the testing kits have been also reported by various other countries of the world. This showcase that unavailability of better and cost-efficient testing methodology appears as a great barrier for the country to fight back the pandemic.

One of the reasons behind fewer tests being conducted is a lack of medical resources. But the proposed concept can be easily adopted as a proposed test can be carried out at any radiology centres.

Research shows that healthcare as a sector has been lagging on the digital transition as compared to other sectors. Today’s response to COVID has accelerated the adoption of virtual and AI tools and their scaling. From the AI bots deployed by various organizations, rapid digital transformation is being employed to counter COVID’s exponentially rising hazard. AI promises a large change in the healthcare sector in the future. As per [6], in 2015 in United States, 10% of deaths were caused due to misdiagnosis. In [7], researchers have developed AI-enhanced microscope providing better microbiological diagnosis. Such type of errors is expected to be removed by using the AI-based system. In this paper, authors have implemented a deep learning-based model for detection of COVID-19 through Chest Radiograph. According to a research, 69% of patients being diagnosed by COVID-19 was found with chest abnormalities at the time of admission in the hospital. Even earlier many researchers tried implementing the same concept for detection of general chest related diseases mostly with computational intelligence-based approach. A similar concept can be even used for detection of the disease using MRI, CT Scans or other radiology. Figure 2 shows a sample dataset for the 2 classes that are being classified by the proposed model in this paper. The dataset considered has been taken from the repository at [8]. The classes are as follows:

(i) **Infected**: The first class in the classification model is the infected ones. The infection may be due to the development of SARS or Pneumonia. Some of the features in the x-rays that define the infection are air space consolidation, Broncho vascular thickening, and ground-glass opacities. Although the abnormality in chest radiographs may only be visible after 4–5 days of onset of general symptoms.

(ii) **Un-infected**: The second class of images are the chest radiographs found with no abnormality at the time of scan.

In this paper, various Convolutional Neural Network (CNN) based algorithms are used to achieve the goal. CNN are based on complex neural network architecture with translation invariance characteristics. It uses various types of mathematical concepts related to advance linear operations. For various intelligent tasks like image classification, recognition, tracking and object detection CNNs can be used. This approach is increasingly becoming popular as compared to traditional methods for image classification [9]. A deep learning model learns in all representations in a hierarchical manner as part of the training process. This stands as one of the key advantages to use these algorithms. In addition, the concept can be used in a quick
test framework. The paper also presents deployment architecture in order to deploy the model in real time. The main focus of this paper is to devise an architecture for early and easy detection of COVID-19 using heatmap filter approach and deep neural network-based algorithms.

2 Literature Review

Since the outbreak of the disease in various parts of the world, various research organization and healthcare institution has started research in this area to develop methodologies and models that can be used for fighting the disease outbreak. Some researchers and research organizations have also started researching in non-technical fields to fight the pandemic. In [10], authors have studied and analyzed the outcome of this pandemic in the various sectors which might help officials to handle this type of situation better in the future. The paper also highlights the possible reason for the failure of handling the situation. Extended study may also help to derive methodologies to fight against those specific reasons. The paper also highlights the need for additional investigation so as to reach out to the hidden causes. Authors
in [11], have presented some of the pathological finding forms one of the infected patients after the biopsy. The result shows that the finding was very similar to that of MERS (Middle Eastern Respiratory Syndrome) or SARS (Severe Acute Respiratory Syndrome). This means that the detection technique of this disease can be somewhere used to derive an architecture for detection of COVID-19. In [12], researchers have developed a system to track down the movement of virus across the globe and have tried to identify the cause of the spread from one country to another. The concept used behind the research is related to another machine learning concept named “Pattern Recognition”. Baidu launched an infrared technology-based device for contactless analysis of body features in order to detect symptoms related to COVID-19. Some companies or researchers have also developed various chatbots that ask for symptoms of the patient to analyse the suspected case and accordingly guides the patient further steps in the test. This service is remotely accessible, making widespread tests possible.

Some researcher has also used intelligent systems majorly based on Deep Learning for disease detection. CNN is widely used in the field of biomedical or detection and analysis with certain added advanced filters and tuning methods [13]. In [14], authors have used CNN and Whale Optimisation Algorithm to classify and diagnose COVID-19 using CT images. In [15], the results show that there is a high sensitivity for diagnosis of COVID-19 when chest CT’s are considered. Moreover, radiograph-based diagnosis is the easiest way to achieve primary tests in various part of the world where healthcare frameworks are not advanced. In [16], authors have used Composite Monte Carlo Simulation to analyse pandemic situation and forecast the future situation. In [17], authors used data augmentation to use the considerably small amount of data for decision making and forecast of pandemic. Data augmentation increases the significance of the amount of data available for modelling. Considering Pneumonia to be an one of the intermediate state of patient with potentially developing COVID-19 disease, authors in [8] used various algorithms to detect pneumonia from CT Scans. They also used image segmentation to extract the infected region from the images. In [18], researchers have developed a machine learning-based model for the detection of Pneumonia using chest x-rays which in turn may help for the detection of COVID considered in a modelled pipeline. According to the World Health Organization, COVID-19 also opens holes in the lungs like SARS, giving them a “honeycomb-like appearance” [19, 20]. The results in [9] show that the onset of disease causes a significant impact on the lungs causing paving patterns. Such changes can be easily detected using radiographs. In [21], authors concluded that the sensitivity of CT for COVID-19 was found to be 98%. Whereas the sensitivity of RT-PCR (Reverse Transcription Polymerase Chain Reaction), a lab method for detection of abnormal pathogen in the body was found to be only 71%. RT-PCR test is done on respiratory sample. These samples can be obtained via various methods. This includes sputum sample, which is thick mucus or phlegm obtained from lower respiratory tract. Apart from this, nasopharyngeal swap as a sample can also be used for the testing. Nasopharyngeal swap is the method of collecting nasal secretions as the
test samples. As per [21], the disadvantages of this test is the associated complexity. Moreover, it suffers from the problems inherent in traditional PCR when it is used as a quantitative method. The problem also includes with the specificity and sensitivity of the test.

3 Proposed Methodology

In this paper, authors implemented multiple models using transfer learning techniques for faster training to optimize the weights of various Deep Convolution Neural Network like Inception V4, VGG 19, ResNet V2 152 and DenseNet on the Chest X-ray dataset. The workflow of the study in this paper has been represented in Fig. 3.

As can be seen from the above figure the process starts with data pre-processing. The dataset used contains certain invalid files which may be certain incorrect x-rays. The size of the dataset is around 300 chest x-rays of infected and uninfected patients each. In some cases, there are CT scans instead of Chest X-rays of the patients which may reduce the accuracy of the model is included in the training. That is why under data pre-processing the removal of just outlier images is must. Later, in the process, authors have applied heat map filters on the images. This helps in increasing the efficiency of feature extraction for the deep learning algorithms. Figure 4 shows some of the training images after applying heat map filtering. The use of heatmap over images are being extensively used for revealing pattern from the image data. In [22], the authors used a heatmap for the analysis of genomic data. Heatmaps can also be used for an initial level of classification as they can be used to define a group of separate or overlapping clusters. It also provides a better scope for accuracy and feature scaling by Neural Networks.

Authors split the dataset into ratio of 9:1 i.e. 270 training images and 30 test images for each class. And then the training data was fed into each model.

- Inception V4: The inception module first started with Inception V1 which used $1 \times 1$ dimension reduction layer and a global average pooling layer at the last which helped the module to outperform the previously existing modules. Later the

![Fig. 3 Layout for proposed architecture](image_url)
inception V4 module was introduced which is trained with memory optimisation with back propagation.

- **VGG 19**: It uses $3 \times 3$ convolutional layer which may have already covered the $5 \times 5$ or $7 \times 7$ layer. It also eradicates the requirement of filter like AlexNet or others. Thus, number of parameters in this case will be fewer providing faster convergence and reduced over-fitting problem.

- **ResNet V2 152**: The core idea behind ResNet is the it’s residual connections by adding additive merges. This has made training of deeper model possible.

- **DenseNet**: Instead of using additions, it concatenates output from previous layer making the model more accurate, deeper and efficient to train. This algorithm strengthens the feature propagations. Thus, in turn reducing the number of parameters.

These four algorithms were then trained on the training heat mapped datasets. And the performance graph was found. The graph and the performance of the models are discussed in the next section of this paper.

### 4 Result and Discussion

In order to decide the algorithm that should be used for the detection of COVID in real sense, it is very important to compare the individual performances of these algorithms. When these modules were used to train the COVID dataset discussed in this paper the epoch wise performance that was found on the validation dataset is shown in Fig. 5.
As it can be seen, the DenseNet module trained on the COVID dataset outperforms the other implemented algorithms. The maximum accuracy attained by DenseNet algorithm in the process was 0.93. The features of all levels are used in DenseNet classifier making it perform better than other classifiers. The results show that the model “DenseNet” though takes more time for training as compared to other algorithm but is worth since its performance over the dataset was found better than the other algorithms. Overall the implemented model showed a high accuracy making it fit to be used for validation in real scenario. If the model is fed with more amount of dataset the accuracy and performance is expected to increase further. Moreover, introducing new scans for training will also cover some novel cases which may appear to be outliers in the current research.

Table 1 demonstrates the maximum and minimum accuracy attained by all the models considering all epochs.

| Model name  | Minimum accuracy | Maximum accuracy |
|-------------|-----------------|-----------------|
| Inception V4 | 0.55            | 0.91            |
| VGG 19      | 0.50            | 0.844           |
| ResNet V2   | 0.55            | 0.9             |
| DenseNet    | 0.55            | 0.93            |
When the performance of the model is closely observed in term of the metric being accuracy, except VGG 19, the maximum accuracy of the other 3 model seems to be similar. Whereas, initially at a smaller number of epochs, all the algorithm didn’t show an acceptable performance metric.

Table 2 shows the validation of model over the sample test data. Heat map filter was also introduced over the test data before feeding it into the model. The algorithm used for validation which is demonstrated here is DenseNet.

5 Deployment Architecture

The model proposed in this paper can be deployed in the Indian scenario as discussed in the case study. Figure 6 describes the deployment architecture.

As it can be seen in the above figure, whenever a person is showing the general symptoms of COVID-19 which are cough, fever and difficulty to breathe, the person can visit the nearest radiology center or clinic. Or in a different scenario, if in case authorities at a rural place wants to screen a suspect in order to detect the presence of COVID-19, the authorities can use this testing method to complete their objective. The radiologist can then take out a chest x-ray of the suspected person. The chest x-ray can be then sent to the model using the mobile phone application installed in one of the devices with the radiologist. The application will send the clicked picture to the model via cloud technology and will also append the image into its dataset along with the predicted label for improving the model. The result will be displayed on the same application within seconds of analysis. Figure 7 demonstrates a quick preview of the proposed mobile application in the deployment architecture. At the same time, if the model detects abnormality in the x-ray of the suspected patient, a message will be sent to the nearest governing body. Later the patient can be move towards the main COVID testing centre where he/she can be lab tested with the respiratory specimen to confirm the results. If there is no abnormality found in the x-ray of the patient by the model, the person can be suggested to be in self isolation till the symptoms exists or may ask for additional help if the symptoms keep on prevailing. This process will significantly lead more number tests being conducted in a day. Thus, identifying a greater number of confirmed cases than the conventional methodology being practised.

6 Conclusion

In this paper, authors have studied a scenario of COVID-19 testing in India and have proposed a few CNN models for image classification to detect COVID through Chest X-rays. The objective of this research was to find a way to make detection of COVID-19 possible in areas with relatively lesser medical facilities. The major outcome of this research are as follows:
| Predicted label | Actual label | Image                      |
|----------------|--------------|----------------------------|
| Infected       | Infected     | ![Image](image1.jpg)       |
| Infected       | Uninfected   | ![Image](image2.jpg)       |
| Uninfected     | Infected     | ![Image](image3.jpg)       |

(continued)
Table 2 (continued)

| Predicted label | Actual label | Image |
|-----------------|--------------|-------|
| Uninfected      | Uninfected   | ![Image](image) |

Fig. 6 Model deployment architecture

- The reason for lesser number of cases being found may be directly associated with, lesser number of tests being conducted in India as far as population is considered.
- The reason for this lack of testing methodologies facility and unavailability in rural or semi urban area.
- CNN based DenseNet algorithm seems to outperform the other algorithm implemented of the dataset.
- The use of heatmap filtering over the dataset helped in getting a better performance due to easy feature extraction and scaling.
- The accuracy of the model can be increased further by adding more images into the training data set.
The performance of the model proposed in the paper was found optimal for the target set in this research. But in case of COVID, some patients are reported with case where they do not develop any kind of visible abnormality in the chest or thoracic cavity. The abnormality is developed or visible in 2nd or 3rd week from the onset of disease. In such cases the test proposed in this paper may not prove to be reliable. However, such cases are rare to happen and will cause delayed detection in case the described model is considered [23].

There is a need of analysis of this concept in real time as per the proposed deployment architecture to understand the feasibility and performance of the architecture. Authors have also worked on Sensor based belts and mask, to record the physiological data of the suspect that directly gets fed into the database via mobile application as described in the architecture. The performance of the concept is expected to increase if the analysis is done along with the correlation of the sensor data. The sensor data...
may include pulse rate, presence of Hydrogen Peroxide which acts as biomarker to
detect the pathogens and microbes which potentially may act as cause of the disease.

The proposed methods perform better than the traditional methods used for classi-
fication. Thus, ensuring a reliable and timely detection and diagnosis of COVID-19
possible. In addition to this, the deployment architecture mentioned in this paper
presents a valid set of process to make this test reliable over the set of population.
Apart from this the extended version of the same concept can be also used for other
disease using some different type of radiological images.

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