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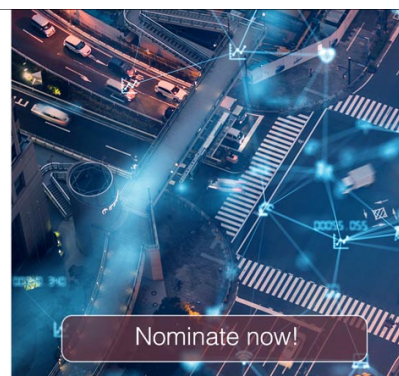


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Classification of COVID 19 in Chest CT Images using Convolutional Neural Network

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Abstract. The single-celled organisms called a virus are the root cause of many harmful diseases that affects both animals and humans. Coronavirus is one type of virus that is usually found in animals but if transmitted to humans can cause a wide range of respiratory diseases. One such disease caused is the COVID-19 diseases which caused a worldwide epidemic since its origin in 2019. The disease which is said to have originated in China had caused more than 252000 deaths worldwide in a few months. The test for the COVID-19 involves analysing the throat swab sample which may take days if not a week and by the time the results come the infection would have spread. Hence there is a need to improve the testing procedure for COVID-19. In this paper, we have come up with an automated Image Analysis technique to diagnose COVID-19 using the chest Computed Tomography images of the chest that uses a Convolutional Neural Network. This developed method has shown very good accuracy and efficiency in recognizing the COVID-19 infected CT images.

Keywords-COVID-19, CT Images

1. Introduction

The Corona virus disease or COVID-19 has extensively affected over 215 countries around the world since January 2020 [1]. China reported its first case with an unknown pneumonia to the WHO Country Office in China on December 31 2019 [2]. WHO identified and termed this disease as Corona virus disease (COVID-19) on 11 February 2020 [2]. COVID-19 was declared a pandemic. As of 3 May 2020, there are 3,485,142 confirmed cases with 244,801 deaths and 1,124,416 recoveries [3]. Countries with the greatest number of confirmed cases are USA (1,160,838 cases), followed by Spain (245,567 cases) and Italy (209,328 cases). India comes under one of the affected countries with 39,980 cases, 1,323 deaths and 10,819 recoveries. The total COVID-19 cases between January 22nd and April 21st 2020, is shown in Fig.1.



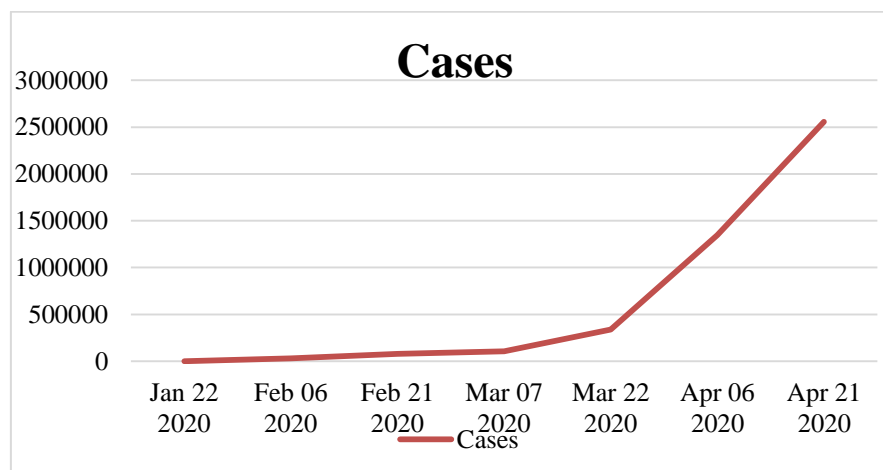


Figure 1 Total COVID-19 cases

The COVID-19 virus spreads when an infected person coughs or sneezes. Maintain a safe distance from anyone who is coughing or sneezing. Some of the symptoms of COVID-19 are fever and dry cough and in serious cases, the symptoms are difficulty in breathing [4]. Due to the long process involved in testing for the Corona virus, many people with this disease are not identified quickly. According to WHO, it normally takes 5 to 6 days for the symptoms to show and it can take up to 14 days. Mostly it affects people who are 65 years and above.

Computed Tomography (CT) of the chest is one of the most important radiological modality, which gives more detailed visualization of the chest region. The National Health Commission of China also reported that Chest CT imaging is useful in the diagnosis of COVID19 disease. The Convolutional Neural Network (CNN) model is designed for the classification based on COVID-19 or normal individual. With the help of the Chest CT images, the proposed model categorizes whether the patient is affected or not. In order to analyse the CT images, radiologists are required. Hence, there is a need to analyse without the involvement of radiologists.

2. Review of Literatures

Researchers have reported a tool called lung ultrasound which is used to detect pneumonia. The relationship between the ultrasound findings and the severity and course time of the disease were observed from the experiments. They also used vascular ultrasound to detect potential deep vein thrombosis and lung abnormalities [5]. When diagnosed, patients showed 100% abnormal findings. B-lines vary from patient to patient. If a patient is critical, it shows confluent B-lines and the rest showed compact B-lines. Hence it showed Bilateral results. Thus, B-lines and pleural abnormalities were detected in individuals affected by COVID-19 disease.

Asma Abbas have devised an image classification technique called DeTraC (Decomposition, Transfer and Compose) which consists of three phases namely Class Decomposition, Transfer Learning and Class Composition. The image features are initially extracted and then the class decomposition phase is administered to simplify the entire structure. In Transfer Learning the image dataset is classified into specific categories with the help of a pre-existing model. Finally, in the composition phase the image dataset previously classified into several subclasses is assembled back to produce the final result. This technique has been able to achieve a high performance with accuracy of 95.12% proving it to be quite efficient [6].

Rachana H.B. and Mallikarjuna Swamy M.S. have published a work for identifying Tuberculosis Bacilli bacteria in a sputum sample using an image analysis technique. The image analysis technique is based on the Otsu thresholding and k-means clustering method. This method has been shown to be accurate and efficient. With the help of this technique, the time and cost expended in manual detection of the bacteria in a sample are immensely reduced [7].

3. Proposed Method

3.1 Deep Learning

The Deep learning technique greatly helps in the process of image classification using neural networks. Neural networks are used to process a large set of data the way the human brain does [8,9]. It consists of many processing units called nodes and each node's output may be an input to another node. Each node's output depends on the weights of the input received and based on the comparison of the calculated weight with the threshold value the node may either provide data to the next layer or it may not. Each layer consists of many numbers of nodes and each layer process the image in a certain way. Before deep learning was introduced there used to be only three layers in the network and they were input layer, mid-layer, and output layer. But this did not give efficient classification. Hence by adding a greater number of middle layers i.e. the processing layers deep learning techniques provide means for image classification with much efficiency [8,9,10,11].

3.2 Convolutional Neural Network

Convolution Neural Network (CNN) is named after the convolution process the network does to extract the feature maps. The architecture of the proposed CNN is given in figure 2. The input image is converted into a matrix form using the colour values of each pixel in the image. This input matrix is then convolved with a filter matrix to get the desired feature map. In this context convolution is the element-wise multiplication of the two matrices and summing up of the obtained values. The formula is given as follows

$$W[i,j] = (f * h)[i,j] = \sum_x \sum_y h[x,y]f[i-x,j-y]$$

There are many filter matrixes to get different layers of the image such as Blur, Vertical lines, Edge detection etc, Deeper layers can be extracted through convolving certain filters with the already extracted feature maps. With the help of these deep layers the network can be made powerful for the process of image classification. After the convolution the resultant matrix is then non-linearized using ReLU function in which the negative values will be assigned the value zero and the positive values will remain unchanged. The mathematical formula for the ReLU function is as follows

$$y = \max(0, x)$$

The size of the matrix will not get altered in this process. The next process is the Pooling process where down sampling takes place to reduce the matrix size. Max Pooling takes the max value in each submatrix to produce a matrix containing only the vital information. This is then vectorized to be fed to the Fully Connected Layer. The FC layer based on the input matrix values predicts to which label the image belongs to by assigning probability values to each node. Based on these values the output node with the highest probability value is selected to be the output [12].

3.3 Dataset Used

The image dataset used here is the Computed Tomography (CT) images of the chest. Computed Tomography is taken through rotating X-ray machines that provide a cross-sectional scan of the body. The dataset is obtained from the GitHub repository: <https://github.com/UCSD-AI4H/COVID-CT>. Two sets of datasets are used i.e., Training and Testing. The training datasets consists of images of positive COVID-19 cases and negative COVID-19 cases for negative training. After the training, the model is validated using the Test dataset which also contains both positive and negative cases. These images are donated by the various hospitals and collected from different sources and are of high quality. The Chest Tomographic images of COVID-19 and non-COVID 19 is shown in figure 3.

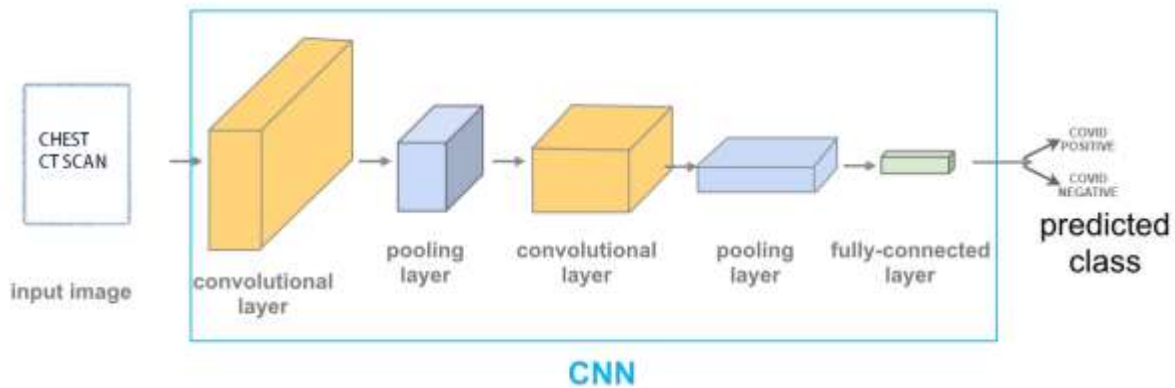


Figure 2 CNN Architecture

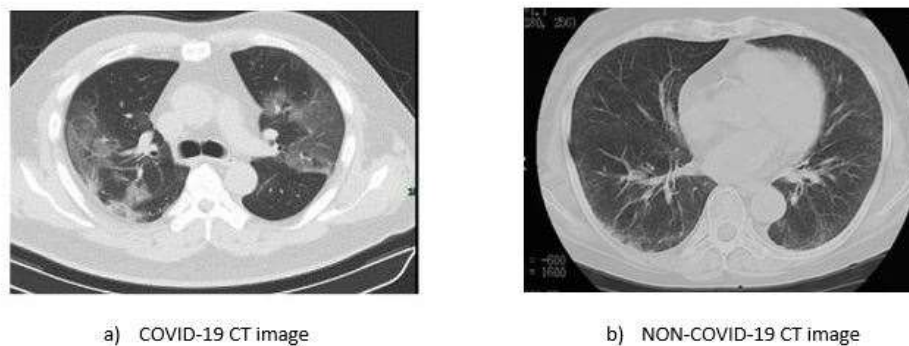


Figure 3 CT images of a COVID 19 and Non-COVID 19 case

3.4 Training the Model

The network model is first created using the Keras module in python. Then the layers for the network are defined and added to the model. Our algorithm uses four hidden layers for better recognition. Each layer has its convolving process and the max pooling process to it. After the network is defined the network is compiled. The dataset to be used is then loaded. Two separate image data generator objects are created, one for training and the other for testing. All the images are rescaled to a specific size before given to the network. The batch size is kept to be eight and 30 epochs are run to get the maximum efficiency with minimal error rate. The weights are varied for each epoch and the model with the minimal error degree is saved. The saved model can be used to build an application that can determine whether a patient has COVID-19 by uploading an image of his/her CT scan of the chest.

4. Results and Discussion

The automated COVID-19 diagnosis using deep learning is tested using the test dataset containing 102 CT images of positive cases and 105 CT images of negative cases. 60 percentage of the images were used in the training phase and remaining 40 percentage of the images were used in the testing phase. During the training the learning rate (α) was kept as minimum. The 29th epoch is chosen as it delivered the classification with the highest accuracy. The accuracy, sensitivity, specificity of the model is obtained from the table given below. The formulas for the three parameters are as follows [13, 14]:

$$Accuracy = \frac{T_P + T_N}{T_N + T_P + F_P + F_N} * 100$$

$$Specificity = \frac{T_N}{T_N + F_P} * 100$$

$$Sensitivity = \frac{T_P}{T_P + F_N} * 100$$

T_P = True Positive, an image belonging to COVID-19 set detected accurately as positive for Covid-19.

T_N = True Negative, an image belonging to COVID-19 set detected falsely as negative for Covid-19.

F_P = False Positive, an image belonging to NON-COVID-19 set detected accurately as negative for Covid-19.

F_N = False Negative, an image belonging to NON-COVID-19 set detected falsely as positive for Covid-19.

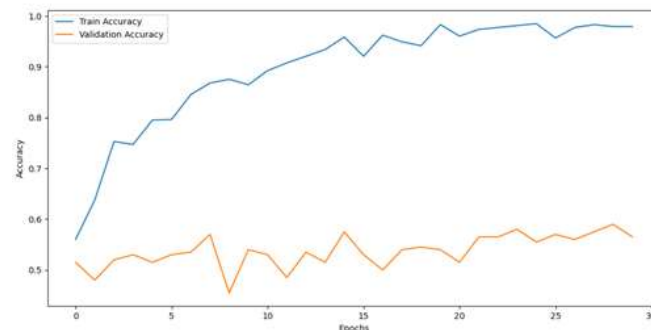
The obtained values for the T_N , T_P , F_P , F_N from training the model is shown in the table 1.

Table 1. Test outcome

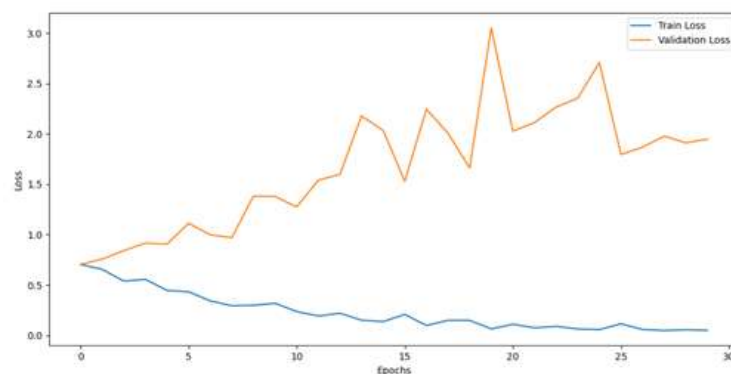
Test outcome	Positive	True Positive 98	False Positive 0
	Negative	True Negative 105	False Negative 4

The sensitivity, specificity and accuracy of our CNN algorithm is calculated as 100%, 96% and 98%, respectively.

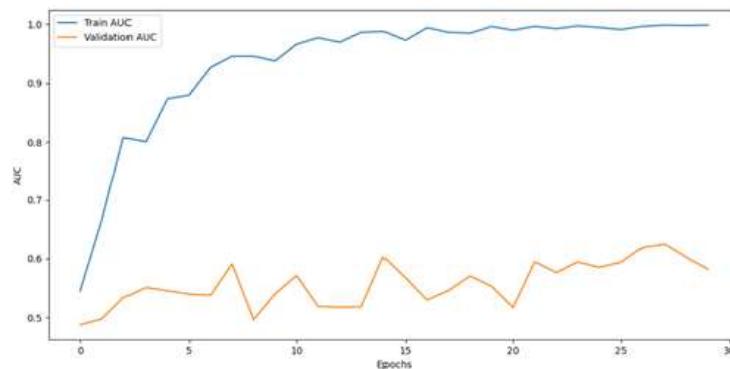
The accuracy, loss function and Area Under the Curve (AUC) with respect to the 30 epochs are plotted as a graph and it can be seen that the 29th epoch shows minimal loss with high accuracy.



(a) Accuracy



(b) Loss function



(c) AUC

5. Conclusion

This system is mainly developed to overcome the drawbacks faced in anomaly detection through analysis of throat swab samples which takes around a week to be examined by the time which the infection would have spread thus deeming it an ineffective technique. The adopted method is also shown to be more effective as compared to conventional techniques of analyzing images manually. The issue of high time requirement is compensated in this technique and this method has proven to be quite competent having been able to achieve an accuracy as high as 98%. The proposed method is simple and cost-effective to be implemented both in rural and urban areas.

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