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Automated Detection of COVID-19 using Deep Learning

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ABSTRACT

Corona virus 2019 (COVID-2019), has first appeared in Wuhan, China in December 2019, spread around the world rapidly causing thousands of fatalities. It is caused a devastating result in our daily lives, public health, and also the global economy. It is important to sight the positive cases as early as possible therefore forestall any unfoldment of this epidemic and to quickly treat affected patients. The necessity for auxiliary diagnostic tools has increased as there aren't any accurate automated toolkits available. Recent findings obtained using radiology imaging techniques suggest that such images contain salient information about the COVID-19 virus. Coupling deep learning techniques with radiological imaging may end up within the accurate detection of this disease. This assistance will help to beat the matter of an absence of specialized physicians in the remote villages.

Key words: Machine learning, Artificial Intelligence, deep learning.

1. INTRODUCTION

An automated model for automatic detection of COVID-19 detection using raw chest X-ray images is presented. The proposal is to come up with a new model to provide accurate diagnostics of COVID-19 using classification methods. The most frequently used testing mechanism currently being employed for COVID-19 diagnosis is a real-time reverse transcription-polymerase chain reaction. Radiological imaging of the chest has crucial roles in the early diagnosis and treatment of this disease [1]. Due to the low RT-PCR sensitivity of around 70%, even if negative results are obtained, symptoms can be traced out by examining the radiological images of patients [2, 3]. It has been found that CT is a sensitive method to detect COVID-19 pneumonia, and can be considered as a screening tool with RT-PCR. CT findings are examined over a long interval after the occurrence of symptoms, and patients generally have a normal CT in the first 2 days. In addition, artificial intelligence-based approaches can be useful in eliminating disadvantages such as the insufficient number of available RT-PCR test kits, test costs, and waiting time of test results. Recently, many radiology images have been used widely for COVD19 detection [2, 3].

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2. RELATED WORKS

In a study on lung CT of patients who survived COVID-19 pneumonia, the most prominent lung disease was seen ten days after the onset of symptoms. At the start of the pandemic, Chinese clinical centers had meagre check kits that are manufacturing a high rate of false-negative results, therefore doctors are inspired to make the diagnosis solely based on clinical and chest CT results. CT is extensively made use for COVID-19 detection in countries where the availability of test kits is scarce. Researchers state that combining clinical image features with laboratory results may help in the early detection of COVID-19. Radiologic images obtained from COVID-19 cases contain useful information for diagnostics. Some studies have come across changes in chest X-ray and CT images before the onset of COVID-19 symptoms. Remarkable discoveries have been realized by investigators in imaging studies of COVID-19. The application of machine learning methods for automatic detection within the medical field has recently gained quality by changing into associate adjunct tools for clinicians. Deep learning, which is a famous research area of Artificial Intelligence, it sanctions the creation of end-to-end models to accomplish the promised results using input data, without the need for the extraction of features manually. Deep learning techniques have been successfully employed in numerous problems such as arrhythmia detection, skin cancer classification, breast cancer detection, brain disease classification, pneumonia detection from chest X-ray images. The COVID-19 epidemic's rapid rise has opened the need for expertise in this field. This has increased interest and demand in developing automated detection systems using AI techniques. It is an arduous task to provide expert clinicians to every hospital due to the constraint of the number of radiologists. Therefore, such simple and accurate AI models will be so much helpful to overcome this problem and provide timely assistance to patients. Although radiologists play a key role due to their vast experience in this field, the AI technologies in radiology can be used for assistance to obtain an accurate diagnosis. Diagnostic tests performed after 5–13 days are found to be positive in recovered patients. This finding implies that the recovered patients as well may continue to spread the virus. Therefore, more accurate methods for diagnosis are needed. The biggest disadvantage of chest radiography analysis is an inability to detect the early stages of COVID-19, as they do not have sufficient sensitivity in GGO detection. However, well-trained deep learning models can focus on points that are not noticeable to the human eye and may serve to reverse this perception. [4].

3. METHODOLOGY

For this model, X-ray images obtained from two different sources are going to be used for the diagnosis of COVID-19. A COVID-19 X-ray image database was developed by Cohen JP using images from various open access sources. This particular database is being updated with images shared by researchers from different regions of the world. As of now, there are around 150 X-ray images diagnosed with COVID-19 present in the database. In a step to avoid the unbalanced data problem, we can use a certain number of no-findings and pneumonia class frontal chest X-ray images (1:1 ratio) from this database randomly. Also several images from other open source repositories and from known sources have been collected. The ratio has been maintained accordingly as mentioned. The emergence of deep learning technology has transformed artificial intelligence. The word deep refers to the accruement in the size of this network with the number of layers [5]. A typical Convolutional Neural Network(CNN) structure has a convolution layer that extract features from the input with the filters it applies, a pooling layer to reduce the size for performance in terms of computation, and a completely interconnected layer, a neural network. By combining multiple such layers, a CNN model is made, and its parameters are modified to realize a specific task, like classification or pattern recognition. To make the best use of the classification mechanisms we should process the input so that it doesn't have any unnecessary features or parameters left behind in it [6, 7]. It is known that not every single minute feature that doesn't actually contribute to the efficiency of the classification can be removed but at least more than half of it can be removed. In our case the input are chest X-ray images which means that the input is an image. This is where image processing comes into play. Modern day computational power and technology along with cutting edge algorithms to play with the pixels has made it possible to achieve marvels. These cutting edge techniques can be utilized in various ways, one of them being processing. Here processing of images is nothing but the preprocessing of the input data that we pass into the model. We are going to employ these techniques to make the classification ability of the model more effective.

3.1. Requirement Analysis

This model needs a dataset of X-ray images with COVID positive and negative [8]. The model helps as a catalyst in the process of COVID detection of a patient with just an input of an X-ray image of the patient. GPU enabled systems with high computing systems will be required for training the model, any cloud GPU providers could be used as an alternative. In this study, we have proposed a deep learning-based model to detect and classify COVID-19 cases from X-ray images. The model is going to be fully automated with an end-to-end structure without the need for manual feature extraction. The developed system is to perform binary tasks with an accuracy of more than 85% respectively.

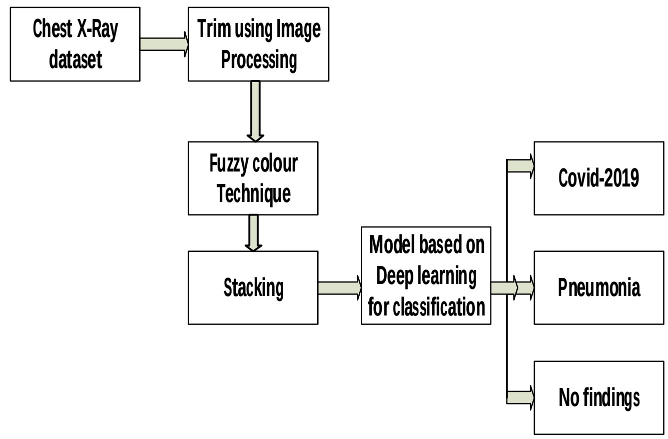

Figure.1. Functional overview of COVID-19 detection.

We can see the holistic design of the model in Figure.1, starting from the collection of dataset to identifying the right image processing techniques that can serve the purpose properly for the classification and detection of COVID-19. After processing the requirement is to come up with a state of deep learning model that can be trained with the help of these images [9]. The deep learning model has to not only be efficient but also should require less computing power so that even systems with low computing power can be used train the model. For example, systems that do not have a GPU should be able to train it as well. This not only ensures that the model can be easy to use in remote areas by just having the required files but also makes it very user-friendly and fast when deployed on cloud as well. With the help of this model even if further technical support is not available for people who use the model, they can easily understand where to place the new X-ray images that they secure as they continue using the model and run the code. This helps in increasing the accuracy as well.

The performance of the developed model can later be assessed by data from open-source which has been analyzed by expert radiologists and is ready to be tested with a larger database. This system can be used in faraway places with less or no medical facilities, to overcome a shortage of radiologists [10]. Also, a similar model can be used to diagnose other chest-related diseases including tuberculosis and pneumonia. The shortage of X-ray images is a limitation of the study [11, 12].

3.2 Deliverables

The following image, Figure.2, shows a detailed structure of what a convolution block consists of, in the final deep learning model. This will further be explained in the latter part of the paper where we can also observe where and how exactly is this block used in the model, also why each layer in the block is is necessary to ensure the efficiency of the final deep learning model, which is one of the core parts of the proposed solution.

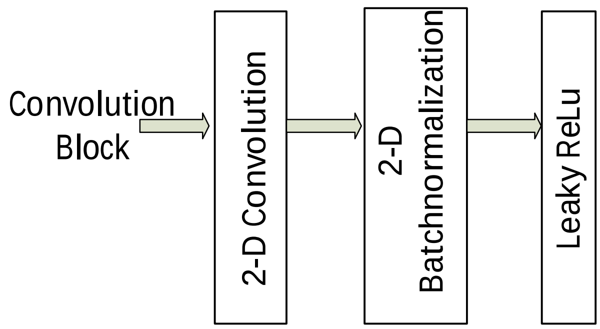

Figure.2. Overview of Convolution block model.

The model designed is for the automatic detection of COVID-19 using X-ray images without requiring any handcrafted feature extraction techniques. The model helps to provide a second opinion to expert radiologists in health centers. It can lead to significant reduction in the workload of the doctors and assist them to make an accurate diagnosis in their daily routine work, hence specialists can focus on more critical cases. The model not only has the ability to detect if a person is COVID-19 positive or not but also it has further capability to know if a person is suffering from pneumonia. The end product would be a program with image preprocessing capability in a way that the input is properly structured for the deep learning model that is followed by it to perform its best while applying the feature filters and pooling on layers. The end product need not be trained every single time for use, once it is trained it can be used for any number of times. However, when more number of images are available it's good to re-train the model so that the efficiency of the model increases. The accuracy increases with the amount of images available for training, the learning rate employed and the number of epochs trained for.

3.3 Algorithm design and analysis

Rather than starting a deep model development from scratch, a more viable approach is to construct a model using the already proven models. So, to design the deep model used in this study, we have taken the DARKNET and RESNET models as a reference to build this model.

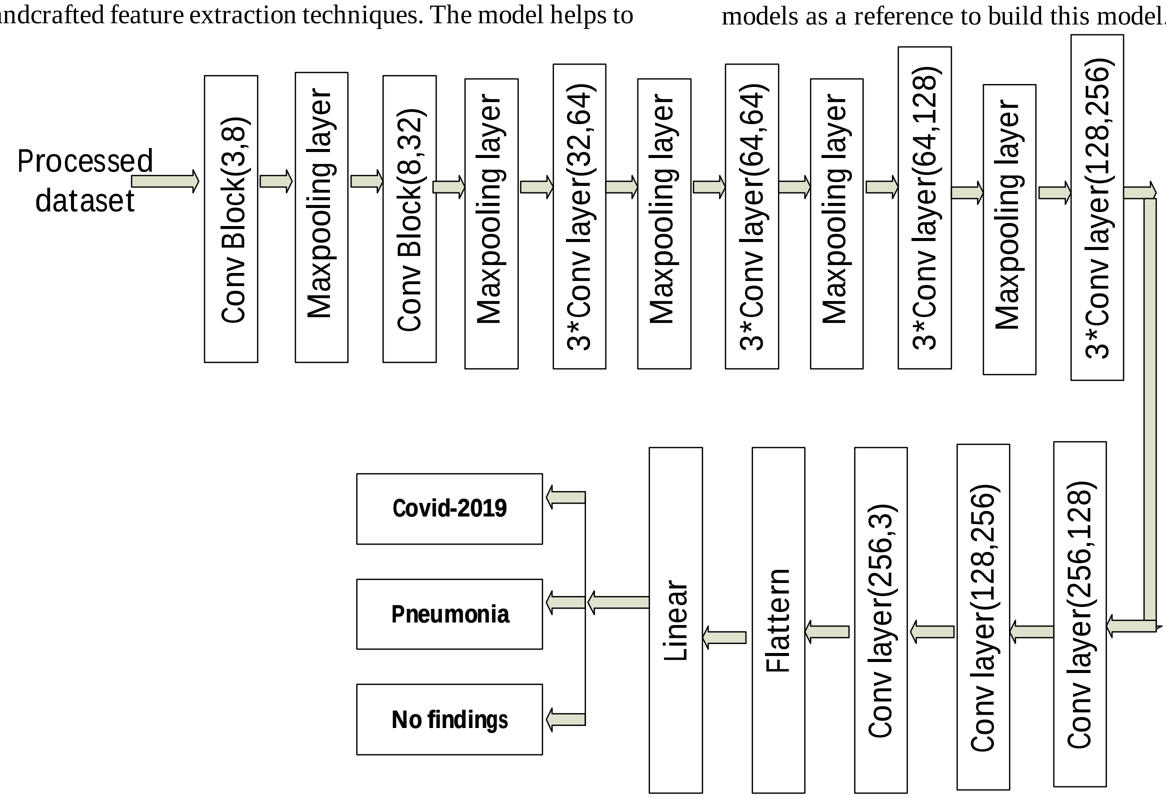

Figure.3. Block diagram of Convolution model in predicting the covid-19.

This system has a very good architecture that can aid in task object detection. Such classifier architectures are employed on the basis of their success. Also there are architectures that are specifically designed for giving efficient classification in the area of X-ray images. A dominant (around 80%) percentage of the X-ray images are used for training and 20% for validation. The model is going to use an n-fold cross-validation procedure for the classification problem. Importantly, in this proposed model, we have added a couple of pre-processing methods with the aim of maximizing the true positives and true negatives. The pre-processing techniques are performed on the image dataset in order to classify and extract only the important features. In recent times many models have taken the advantage of filters in the goal of detection of the required class but the most important thing to take into account here is that some things that are actually common in almost every single data item may not be the desired feature. Considering our case, we have the data item as an X-ray image but actually, there are things that are common in almost all the X-ray images but actually do not contribute to the classification in any way but in fact, may impact the efficiency of classification. Some of such things are the logo, font and time stamp embarked on the X-ray image which is of no use, by pre-processing we can remove these undesirable characteristics of the input data item or the X-ray image to keep it simple. Not only that we can trim the images up to an extent that the surrounding useless addendum is maximally minimized in a way so that it doesn't have any weight in the classification. To achieve this, we are going to use image processing techniques, namely masking, fuzzy colour and stacking. The mask with a combination of edge detection can be used to remove the useless addendum. The fuzzy colour technique makes the image more structured followed by which it is stacked along with the original untouched dataset of images. This is then passed into the proposed neural network. The proposed model as a whole increases the efficiency of the classification of chest X-ray images as COVID-19 and normal. Most importantly it helps us avoid the false positives and false negatives to the maximum extent. The loss graphs, confusion matrix and the required visualization plots in results section. This model finishes with Avg Pool and Softmax layers that generate the outputs. Eventually, a model with a big number of layers is essential for the feature extraction of a real-time object detection system. We will employ only fewer layers and filters as compared to the sophisticated architectures of deep learning models used for classification because the purpose of this model is just not efficiency but efficiency with light weightedness. This light weightedness helps in deploying the model in an environment with very minimal computing capabilities. We may gradually increase the number of filters such as 8, 16, and 32. The proposed model will have several convolution layers as listed above. Each Conv layer has the same setup three times in successive form. The batch normalization operation will be used to standardize the inputs, and this operation also has other benefits, such as reducing training time and increasing the stability of the model. LeakyReLU operation is used to prevent neurons from dying. LeakyReLU has a small epsilon value to overcome the dying neuron problem. Similar to the Darknet deep learning model, the Maxpool method is used in all the pooling operations. Max pool downsizes an input by taking the maximum in the given region (based on the size of the filter) determined by its filter. So to keep it simple the sequence is as follows, preprocessing of dataset using image processing, followed by which the dataset is passed into the convolution block. Clear visualization of the convolution block is shown in the Figure.2,it consists of a 2-D convolution followed by a 2-D batchnormalization layer and a Leaky ReLu. The reasons for using each of these layers in the convolution block has been discussed above.

The layer layout of the model is as follows along with Figure.3:-

Processed data➔CB(3,8)➔MP➔CB(8,32)➔MP➔3*Conv(32,64)➔MP➔3*Conv(64,64)➔MP➔3*Conv(64,128)➔MP➔3*Conv(128,256)➔CB(256,128)➔Conv(128,256)➔Conv(256,3)➔Flatten➔Linear

CB : Convolution block.

Conv : Convolution layer

MP : Maxpooling layer

4. EXPERIMENTAL RESULTS

The proposed model as a whole increases the efficiency of the classification of chest X-ray images as COVID-19, pneumonia and normal. The graphs show the values of training loss, valid loss and accuracy with respect to the number of epochs the model has been trained for. The accuracy and proposed vs existing model graphs as well have been provided.

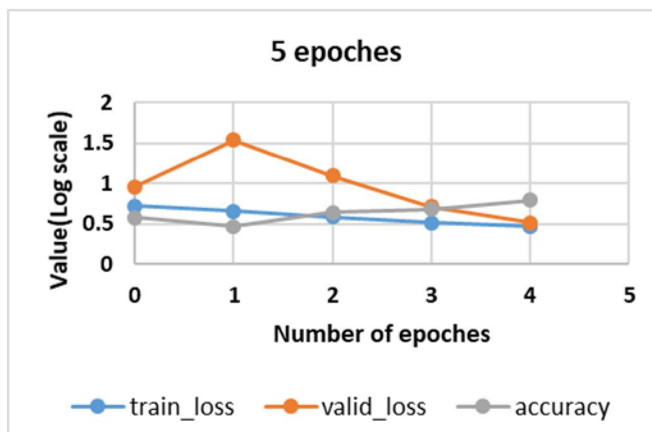

Figure.4. 5 epoches with respect to train_loss, valid_loss and accuracy

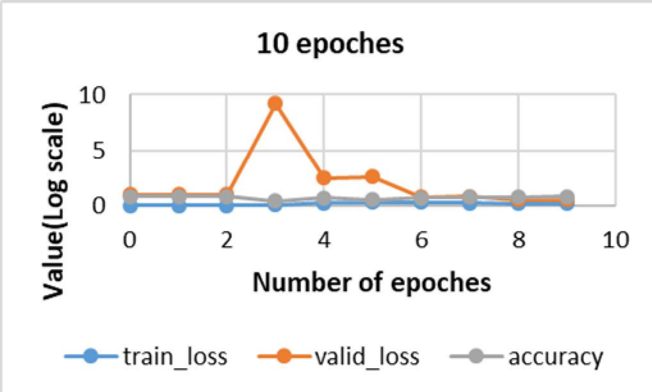

Figure.5. 10 epoches with respect to train_loss, valid_loss and accuracy

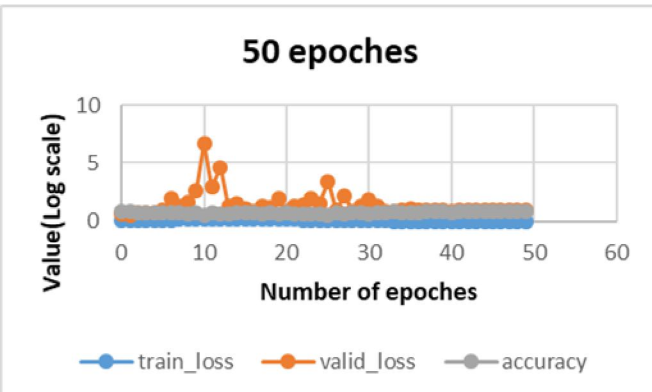

Figure.6. 50 epoches with respect to train_loss, valid_loss and accuracy

	COVID-19	Pneumonia	No Findings
COVID-19	100%	0%	4.6%
Pneumonia	0%	85.4%	6.1%
No Findings	0%	14.6%	89.3%

Figure.7. Detecion matrix using convolution layer

Most importantly it helps us avoid the false positives and false negatives to the maximum extent. Please find the valid-train graphs for 5, 10 and 50 epochs along with the plot confusion matrix from Figure.4, Figure.5, Figure.6 and Figure.7. The graphs clearly show that as the number of epochs the model is trained for is increased the accuracy of the model also increases. For significant improvement we need more input images and have to select a suitable learning rate also play a key role. Here while training we have chosen a learning rate of 0.03. The confusion matrix shows how less the deviation is from the actual result. And like emphasized more number of input images or increased number of epochs while training can even tackle this small gap as well. We compare our deep learning model with an existing model which is based on the Darknet-19 architecture to understand how better the proposed model is than the existing one. Please find the graph depicting the same in Figure.8. We can clearly see that the proposed model is way stable and more consistent than the existing deep learning model. Also, the accuracy of the proposed model clearly outperforms the existing model. As the number of epochs increased this difference became more evident. The model based on deep learning which already exists has outperformed many models which were based on DarkCovidNet, M-Inception net, VGG-19 [4].

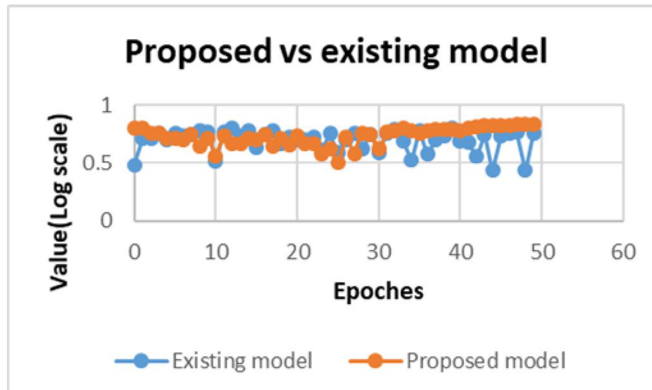

Figure.8. Comparison of existing model with the proposed solution

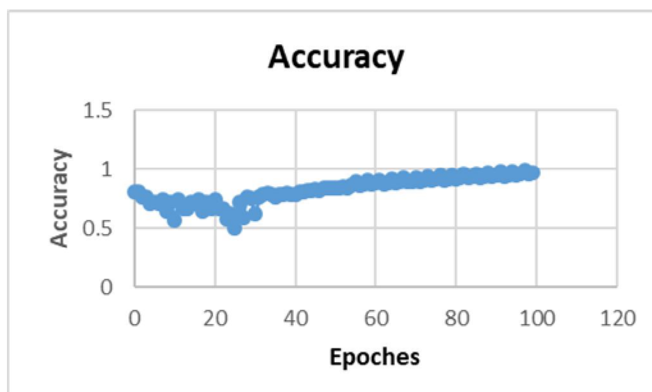

Figure.9. Accuracy with respect to number of epoches

We can see from the Figure 9., that the accuracy of the model is 96.55% after training for 50 epoches, this clearly shows that the model is very suitable for practical use.

Figure.10. (a) Day 1 lung x-ray of COVID-2019 patient

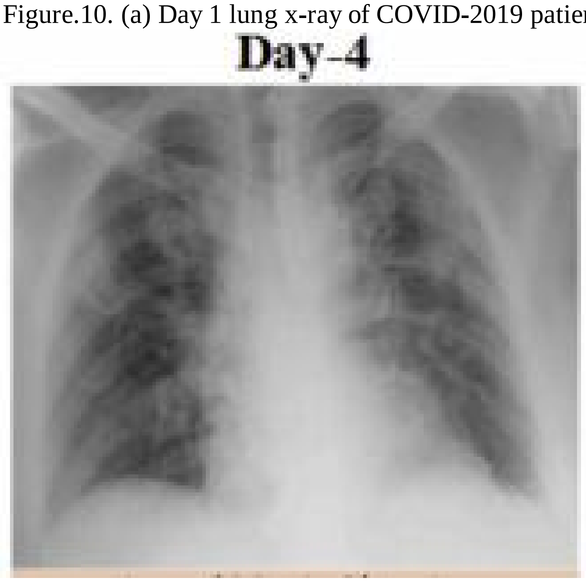

Figure.10. (b) Day 4 lung x-ray of COVID-2019 patient

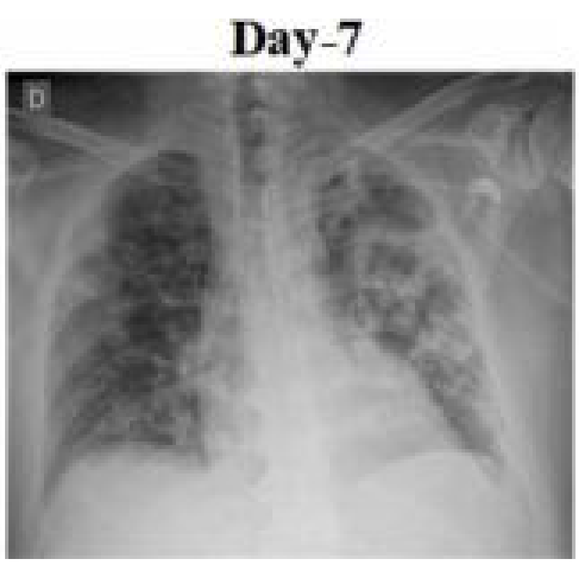

Figure.10. (c) Day 1 lung x-ray of COVID-2019 patient

5. CONCLUSION

We have come up with an affective approach to tackle several challenges faced in the detection of COVID-19, RT-PCR kits give false-negative result which may worsen the situation in the locality where the person lives. Also the availability of RT-PCR kits is limited at most of the places. At certain places even if kits are available there are not enough sufficient testing personnel. So, to overcome these issues that are being faced, tremendous research has been done by many scientists. It turned out that chest X-Ray images and CT-scans can be used to detect if a person is COVID-19 positive or not. CT-scans are costly and also have a radiation impact worse than X-ray on the person, whereas X-ray is affordable and also the radiation effect is comparatively low when comared to the radiation level of the CT-scan. Now, to examine a chest X-ray image and identify if a person is COVID-19 positive or negative a very skilled and experienced radiologist is required. Moreover, there is a chance that during the early onset of the virus the radiologist may not be able to identify it. Figure.10 (a), (b) and (c) show how the regions of chest look when a person is suffering from COVID-19 on day 1 ,4 and 7 respectively. So, with the help of advances in technology and deep learning techniques we have come up with a model which can avoid the false negatives while detecting COVID-19. Most importantly, it doesn’t require a technical person i.e. a radiologist to examine it.The number of radiologists with high skill levels and experience is not adequate enough to serve all the places. There are many remote places where there are no radiologists available at all, at such places this model can be of high use. Also, at normal places as well this model can be used, the model can easily detect the early onset of COVID-19 with high accuracy because the computation power is exploited to the best possible degree by the proposed model.

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