REVIEW ARTICLE

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Diagnosis and Detection of Lung Infection from CT Images using Convolution Neural Network

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Abstract

In the current scenario, the world is facing a challenging problem as COVID-19 which originated in the city of Wuhan in China and has now spread its roots across the entire world. The world has faced this hazardous situation with a large number of people getting affected by the virus. There are different methods presented by researchers for early diagnosis of COVID-19 that helps in giving prioritized and quick treatment action to high-risk patients. This leads to optimized utilization of medical resources to patients. This paper presents an analytical review on the application of artificial intelligence for the early diagnosis of abnormalities. Out of all AI techniques, deep learning proved its efficacy for prognostic analysis of COVID-19 using commonly used computed tomography.

Keywords: Computed tomography (CT), Coronavirus, COVID-19, Deep learning, Viral pneumonia.

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Introduction

The recent pandemic outbreak of unusual viral pneumonia termed novel coronavirus or COVID-19 in Wuhan city of China has rapidly crossed all bar for infecting people worldwide.[1] It was started in December 2019 in Wuhan city of, China. Approximately 40 pneumonia cases were reported out of them; some are vendors or dealers of the Huanan seafood market.[2] World Health Organization (WHO) and Chinese authorities started to research and declared a new virus termed Novel Corona Virus (COVID-19). Within a few weeks, the infection of the new virus spread globally in a rapid pace. By analyzing its impact all over the world, WHO declared it a Public health emergency of International concern on 30th January 2020. On 11th February, WHO announced it as COVID-19.[3] On 11th March, COVID-19 was declared a pandemic because till now it has affected about 114 countries worldwide.[4-6] In India, on 30th January, the first case of coronavirus pandemic was reported. As on 19th August 2021, WHO reported 212,560,109 cases of COVID-19 in about 213 countries out of which 4443,976 deaths were reported (Figure 1). Similarly, in India, WHO have confirmed a total of 32,449,306 cases7 out of which 434,784 deaths were reported.

Coronaviruses is named due to its outer protein envelope resembling a crown and belong to the family of enveloped RNA virus. Generally, coronavirus is pathogenic to animals, and when it gets transmitted from animals to humans and causes respiratory tract infection.[6]

According to WHO several guidelines on infection prevention and control (IPC) strategies for use when suspected of infection from novel coronavirus (COVID-19) are issued. WHO has adapted it as healthcare preventive measures during confirmed cases of infection of Middle East respiratory syndrome coronavirus (MERS-CoV)[8] and severe acute respiratory syndrome (SARS-CoV).[9] This guideline of WHO is summarized on water safety, sanitation and wastewater and faecal waste management relevant to coronaviruses.[10]

Currently, COVID-19 diagnosis is based on Reverse Transcription Polymerase Chain Reaction (RT-PCR), which detects the nucleic acid of the virus present. In this method, a swab is taken from the sputum or nasopharyngeal. So, this testing is not available everywhere and is quite difficult to perform. While the such a testing process is time-consuming as well, gives very low accuracy rate with high complexity.[11-13] Hence, there is a requirement of an alternative diagnosis tool or method. Deep neural networks (DNN)4 have shown great achievement in many applications. As a result, many

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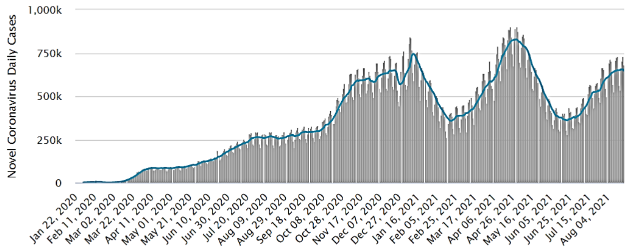

Figure 1: Worldwide COVID-19 Cases (Source: World Health Organization)[7]

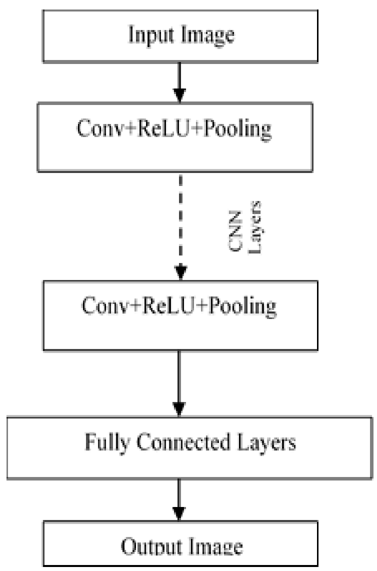

Figure 2: CNN Architecture

researchers adopted the DNN for the diagnosis of COVID-19 infection. This approach shows an advantage over the traditional method in terms of efficiency and adaptability. Application of DNN for COVID-19 detection requires chest X-ray or computed tomography (CT) in order to train the model for automatic classification of infection.[8]

In this paper, the different lung infections are discussed. In further sections, the difference between normal and covid-19 lung infection is discussed. This paper is mainly focused on studying the performance level of different deep learning approaches used for detecting covid-19 lung infection and its differentiation with other infections.

Literature Review

Recently, the deep learning approach has gained attention in the field of image processing. Many research works focus on detecting infected patients of COVID-19 using radiological imaging or CT images.[16] For example, in[17] a deep CNN model was designed to process CT image for detecting COVID-19 cases.[17] İn[18,19] authors used chest x-ray and CT images, respectively. In both research works, the author focused on finding the infection location, and the probability of infection is calculated.

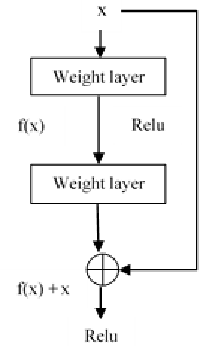

Figure 3: Residual Deep Neural Network Architecture

Similarly, in[20-31], different CNN models were modeled to diagnose COVID-19 infection in CT images (Figure 2). But it is quite a challenging task. Some of them are discussed below:

- The high variation in texture, size, and position of infections in CT slice.
- Unavailability of labeled data for training deep model in a such pandemic situation.
- Expensive and requires more time for processing.

Hu *et al.*[16] proposed weak supervised deep learning for the detection and classification lung infection that occurs during COVID-19 using CT images. The proposed method minimizes the requirement for CT images capable of accurately distinguishing between COVID infected and non-COVID infected. Li *et al.*[24] developed a deep network termed COVNet to extract visual features taken from CT images. This network could distinguish between infection and non-infection visual images but could not declare the severity of this disease. Gozes et al.[25] designed and developed an artificial intelligence tool to detect COVID-19 cases from CT images. This system achieved a sensitivity of 98.2% and a specificity of 92.2%. The system is robust against pixel spacing and layer thickness. Shan *et al.*[26]used the VB-net, CNN model to automatically identify infected regions inside lungs on chest computed tomography. Xu *et al.*[27] used a deep learning approach to create a model to distinguish between COVID-19 pneumonia condition and influenza. For this CNN is used and achieved 86.7% of accuracy. Wang *et al.*[28] proposed a model capable of examining changes that occur due to chest infection in coronavirus. For the prediction of normal and infected CT images deep learning model was proposed. The accuracy obtained in this model is approx 90% which shows achievement over Xu.[27] Narin *et al.*[29] designed and developed a convolution neural network (CNN) based model capable of detecting radiography from a chest infection that is caused due to COVID-19 infection. Different CNN models such as ResNet and Inception was analyzed for performance. Sethy *et al.*[30] used X-ray images as input to CNN model that can extract deep features and classify these images as infected or not. Fan *et al.*[31]presented a deep neural network called Inf-Net, designed to detect infection from chest CT scans. This network was semi-supervised that required mostly unlabelled data.

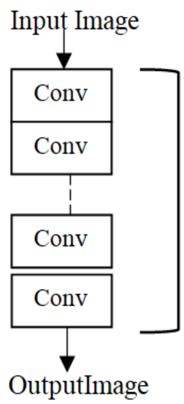

Figure 4: Recursive Convolution Neural Network Architecture

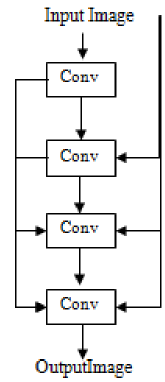

Figure 5: Dense Convolution Neural Network Architecture

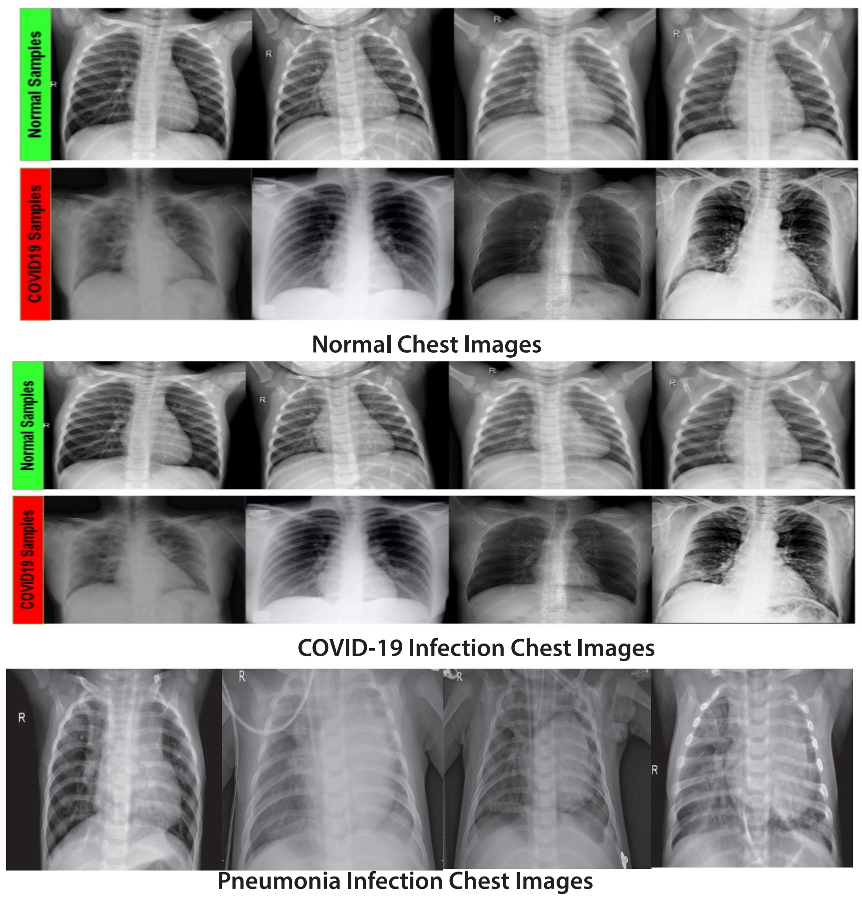

Figure 6 Samples of chest X-ray İmages for Normal and Different Lung Infections

Convolution Neural Network Design

Deep learning has the ability to solve real-world applications. CNN is, therefore, one of the best deep learning algorithms that outperform with the greatest accuracy. The backpropagation process is used to train the CNN. The CNN is trained using the mechanism of reverse propagation. The specifically designed neural network schemes are introduced in images that have a slightly different architecture than the usual structure, and one of the major characteristics of the convolution network is that it is not, as in previous layers, a completely connected network with each other, and each node is interconnected. The CNN consists of four key elements: [14]

- Convolutional layer
- Batch Normalization
- Max Pooling layer
- Rectified Linear Unit
- Fully connected layer

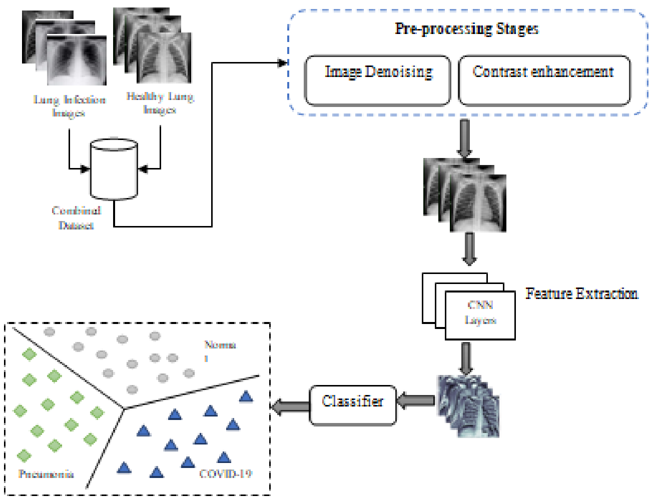

Figure 7: General framework for processing and identification of lung infections

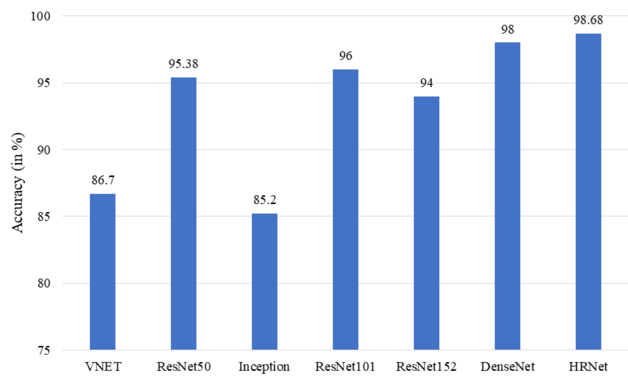

Figure 8: Performance comparision of exiting cnn models for lung infection detection

Convolution: The network-based feature set is reduced by convolutionary operations.

Batch Normalization: This layer is added to speed up the workout.

Max Pooling Layer: The pooling layer aims to decrease the dimensions of the network's previous layer. CNN can be integrated in any order with convolution and pooling layer. However, large concentration and bundling layers create computer complexity and the risk of overfitting.

Activation Function: Rectified Linear Units (ReLU) are internal layers activation functions of CNN design that have the primary role of activating the network. The negative coefficient values are regarded as zero in this unit. eqn (i) calculates the mathematical condition in this layer:

$$f(x) = \begin{Bmatrix} 0 \ for \ x < 0 \\ x \ for \ x \geq 0 \end{Bmatrix} \qquad \text{(i)}$$

This layer doesn't participate in the network's backpropagation, reducing the complexity of the entire training process.

Fully-Connected Layer: Generally in CNN architecture, fully connected layer is considered to be as last layer that generates thefinal decision or output for entire network.

Residual Learning

Very deep neural network are difficult to train because of vanishing and exploding gradient types of problems in this research and will get information about skip connections which allows you to take activation from one layer and suddenly feeded in another layer even much deeper in a neural network and which enables you to train very deep in that called residual block (Figure 3).

Recursive Learning

A recursive neural network is a sort of profound neural network made by applying a similar arrangement of loads recursively over an organized contribution to create an organized expectation over factor size information structures, or a scalar forecast on it, by navigating a provided structure in topological request (Figure 4).

Dense Learning

The feature maps of each layer are proliferated into every single consequent layer, giving a viable method to consolidate the low-level highlights and significant level highlights to help the recreation execution. Moreover, the dense layer of skip associations in the system empowers short ways to be constructed legitimately from the yield to each layer, easing the evaporating inclination issue of profound systems. In addition, deconvolution layers are incorporated into the system to gain proficiency with the up-examining channels and to speed up the reconstruction procedure. Consider an image that is gone through a convolution layer. The model contains L layers, every one of which actualizes a non-direct change H', where ' lists the layer. H' can be a composite collection of activities, for example, Batch Normalization (BN), Rectified linear units (ReLU), Pooling, and Convolution (Conv) (Figure 5).

Loss Function

The loss function is used to determine the difference between results of forwarding propagation of neural networks. Generally, cross-entropy and mean square error loss function is used in most of network, either for binary classification or multiclassification. So, the loss function can be considered to be an important parameter that leads to better efficiency of the model. New studies have progressively focused on the implementation of misfortune to obtain a further recognizable highlight, which implies conservation of intra-class and the discretion of classes as soon as possible. These strategies can work marvelously, and the precision can be improved thanks to the CNN's small-fitting abilities. The loss function was improved by many researchers. The common cross-entropy loss function is very helpful and used in picture processing due to the benefits of available theory, fast training, and excellent performance. The neural network training process is driven by the loss function. MSE (L2 loss) and cross-entropy loss are commonly employed to improve picture classification, while the L1 loss function is employed for regression problems. Table I discusses some of the contributions.

Performance Analysis of CNN on Lung Infections

In this section, an analytical performance study is performed for lung infection detection using CNN. Lung infection is classified into normal, bacterial, viral, and COVID-19 infections. For this, some of the x-ray images of chest infection[32]are presented in Figure 6. While deploying CNN for infection detection, some major contributions are presented in this section. Proper feature extraction from raw input data leads to efficient and robust analysis. Another issue is imbalanced data size leads to training issues of CNN models, whereas high dimensional data size of images leads to overfitting problems while training. Therefore, researchers have focused on several strategies such as data augmentation, the transfer learning process of CNN, loss function of CNN, fine-tuning, etc.

The general block diagram of CNN-based lung infection detection is presented in Figure 7. Some of the important contributions of researchers are focused on pre-trained networks such as ResNet50,[29,30] Inception,[28] ResNet101, ResNet152,[30] DenseNet,[33] HRNet.[34] Their performance comparison is presented in table 2, and their graphical comparison is presented in Figure 8.

CONCLUSION

In this paper, different methodologies for lung infection classification are studied. The paper shows an application of such methodologies to differentiate among other lung infections as well as COVID-19 infections by using deep image processing of chest CT images. The CNN model is the most effective model for detecting and segmenting COVID-19 lung infection to other regions and can be integrated into a unified framework. This paper gives a comparative analysis of different CNN models, which would redirect towards developing a more efficient model in the future.

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