Specialized covid-19 detection techniques with machine learning

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Specialized covid-19 detection techniques with machine learning

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Abstract: COVID-19 has been declared as a pandemic in over 200 countries of the world.COVID-19 is an infectious disease that is primarily caused by severe acute respiratory syndrome coronavirus 2((SARS-CoV-2). According to the latest figures by the world health organization, the number of confirmed cases for the COVID-19 pandemic worldwide is more than 20 million worldwide and the number of fatalities reported is over 700,000. It has been found from several studies that medical imaging coupled with machine learning methods holds great promise in the detection and follow-up of the COVID-19 disease due to the enhanced accuracy in results of the experiments performed by the researchers. Machine Learning (ML)-based solutions can be used to simultaneously analyze multiple input computed tomography (CT) images of chest and lungs. A large number of papers have been published that show the application of machine learning methods in successful detection of the COVID-19 disease. Such applications demonstrate the suitability of feature prediction, identification of involved risks and therefore managing and intercepting the outbreak of such diseases. This paper describes some of the techniques in machine learning that can be used detection of COVID-19 disease.

Keywords: SARS-CoV-2, COVID-19, CT scan, image processing, Machine Learning, Deep Learning.

1. Introduction

COVID-19 is an infectious disease that is primarily caused by the severe acute respiratory syndrome coronavirus 2((SARS-CoV-2) of the genus Betacoronavirus [1].In comparison with other strains of coronavirus such as the severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus (MERS-CoV), the SAR-CoV-2 is highly contagious with a rapid transmission capability leading to the onset of respiratory distress symptoms and even death[2,3].TheCOVID-19 has been declared as a pandemic in 213 countries owing to the steep increase in the number of confirmed cases as is evident from the papers published by different research studies[1, 4]. According to the latest figures by the world health organization(WHO), the number of confirmed cases for the pandemic is more than 20 million worldwide and the number of fatalities reported is over 700,000[5]. The COVID-19 disease is a pandemic and a worldwide catastrophe as suggested by the United Nations which is directly affecting the lives of billions of people worldwide in terms of economic, environmental & social developments. The pandemic is spreading through newer means and its mechanics is yet to be sufficiently understood [11].The structure of coronavirus can be understood with the help of the figure-1 below-

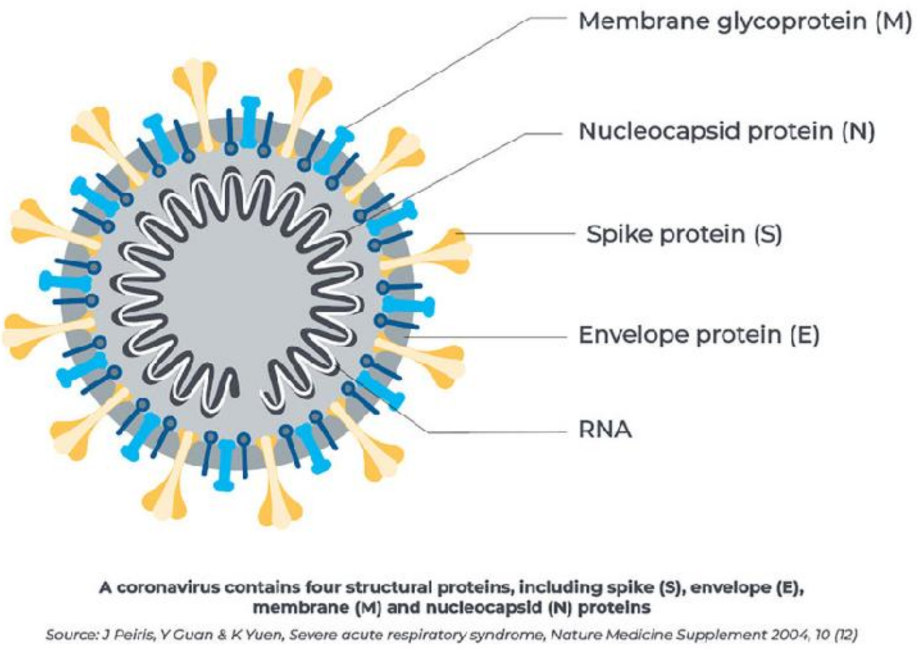

Figure-1 Coronavirus Structure

(Image courtesy:https://www.prnewswire.com/news-releases/beckman-coulters-sars-cov-2-igg-antikorpertest-erhalt-die-ce-kennzeichnung-und-ist-in-deutschland-verfugbar-880278820.html)

It has been found that the SARS-CoV-2 is mainly transmitted through minute droplets exhaled by an infected person through sneezing, coughing, or close interaction with non-infected persons. These droplets can then be inhaled, or they can land on surfaces that others may come into touch with, who can then get infected when they contact their eyes, mouth, or nose.

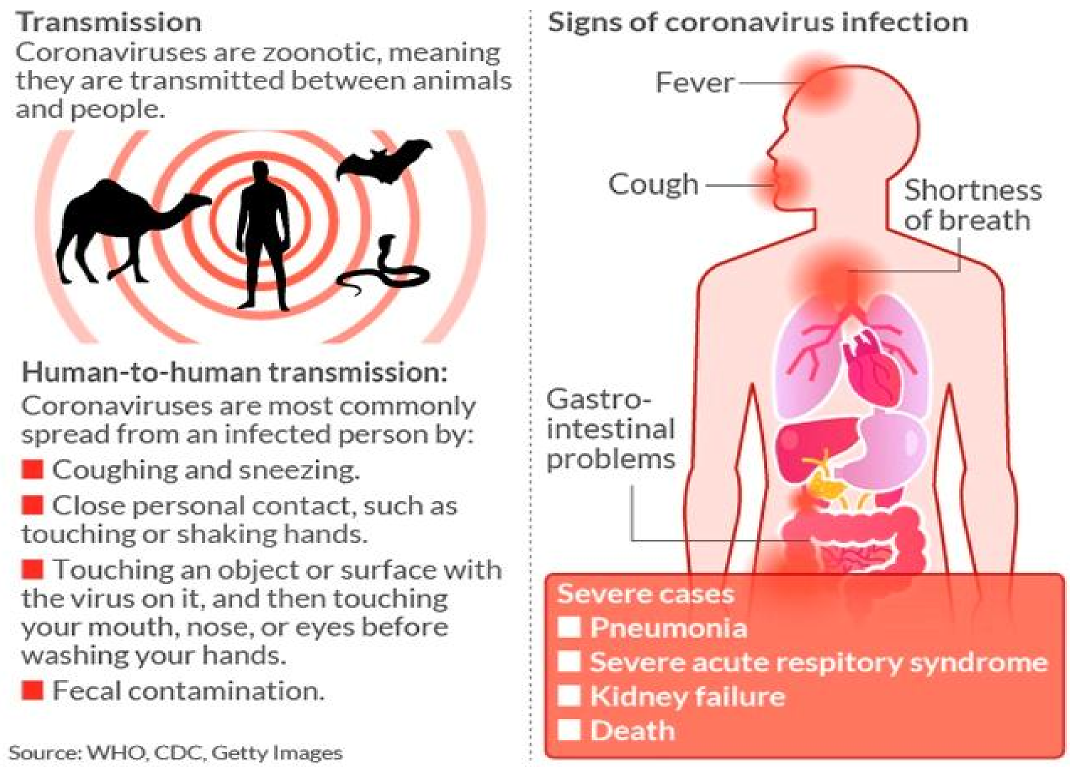

Figure-2 Transmission of coronavirus

(Image courtesy: https://www.marketwatch.com/story/scientists-examine-speed-and-distance-of-coronavirus-transmission-when-people-cough-sneeze-speak-and-run-2020-06-23)

There are several stages involved in the spread of the virus which is described below-

Stage 1- Imported Cases: These are those who have traveled to virus-hit foreign countries and have come back to India.

Stage 2- Local Transmission: These are those cases that have come in contact with patients who have a travel history.

Stage 3- Community Transmission: Community transmission is when a patient not exposed to any infected person or one who has traveled to any of the affected countries tests positive. Large areas get affected when community transmission takes place.

Stage 4- Epidemic: This is the last and the worst stage where the disease takes the shape of an epidemic with no clear endpoint like it did in China.

Machine learning (ML) is a branch of artificial intelligence that deals with algorithms that can continuously evolve and improve through experience [14]. ML algorithms typically build a numerical model based on available data, known as "training data", for purpose of prediction without being explicitly programmed to do so. Generally, ML algorithms are used for applications where it becomes cumbersome or infeasible to employ or build models using conventional programming algorithms. Today however we find that the ML algorithms are being used effectively for a large number of applications involving robotics, computer vision, data mining & forecasting.

Deep learning is a subset of the machine learning paradigm which deals with artificial neural network algorithms that follow the structure and function of the human brain. Deep learning is concerned with deep neural networks that employ a large number of network layers for operation. Due to the usage of a large number of layers, the performance continuously increases as we train the network layers with more data. An important characteristic of deep learning is called feature learning which allows for automatic feature extraction from raw data. Deep learning methods aim at learning feature hierarchies with features from higher levels of the hierarchy formed by the composition of lower-level features. The hierarchy of concepts allows the computer to learn complicated concepts by building them out of simpler ones.

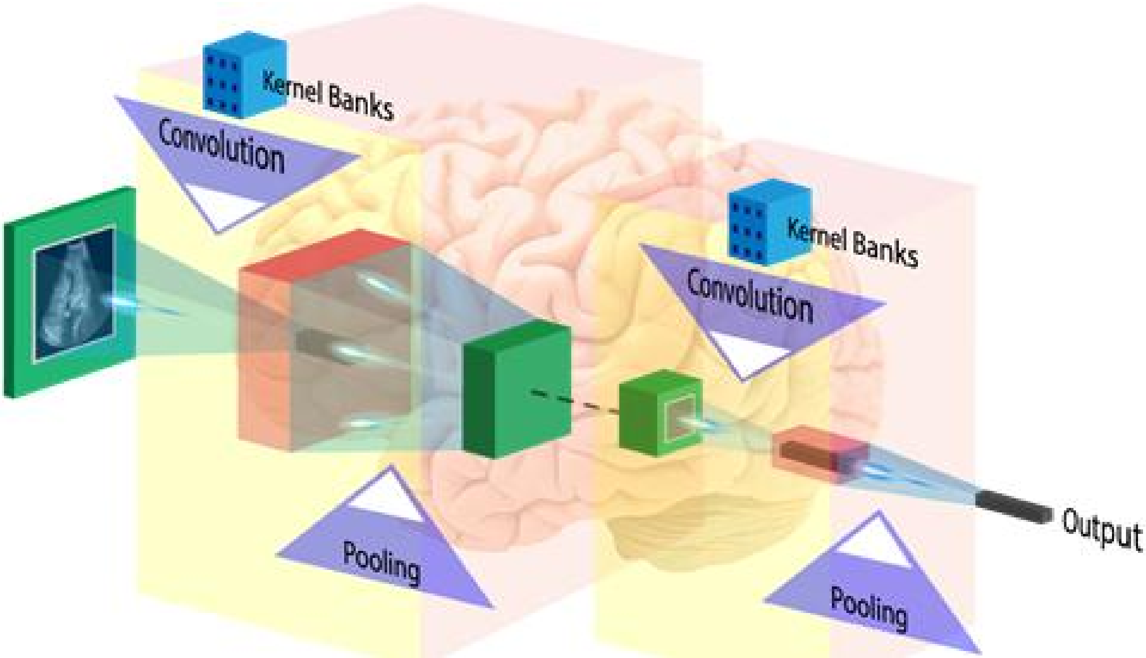

Figure 3 A basic convolution neural network model (image courtesy: AtheroPoint™)

Medical imaging can be used to create a visual representation of the interior portion of the human body so that anomalies can be detected and further intervention can be carried out. Medical imaging modalities such as thoracic, chest, and lung CT scans are widely being used in the diagnosis and follow-up of the COVID-19 disease. These imaging techniques coupled with ML solutions are quite effective in the early detection of disease. The major advantage of such methods is better prediction capability, lower miss diagnosis rates, and lowers the workload of radiologists [1].The imaging techniques along with ML can also be employed for classification and positive confirmation of COVID-19 from also a large number of cases analyzed in a short period [4].

Techniques such as deep learning (DL) enable the effective management of COVID-19 patients and can help avoid transmission [6, 7, 8].The imaging techniques[1, 4, 6]commonly used for positive confirmation and detection of the COVID-19 are low resolution computed tomography (LR CT), High resolution computed tomography (HR-CT),Non-contrast thoracic CT, etc as shown in Figure 5. Convolutional neural network-based approaches have been used for screening and detection of COVID-19 from X-ray image datasets [11, 12]. This review is dedicated to the study of some ML techniques for the detection of COVID-19.The paper is divided into nine sections: section 1 gives the introduction. Section 2 describes some specialized CNN models used for COVID-19 detection and 3, 4, 5, 6, 7, presents 5 working ML models for the classification of lung CT images, classification of X-ray images and detection of COVID-19 disease. Finally, the paper concludes in section 8.

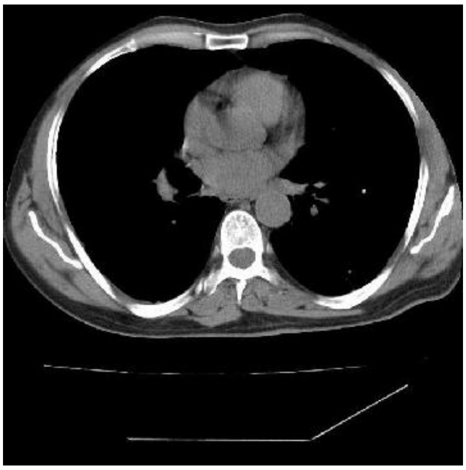

Figure 4 Lung CT image infected by COVID-19 pneumonia (image courtesy: https://radiopaedia.org/cases/covid-19-pneumonia-26)

2. Specialized CNN models for COVID-19 detection

COVID-19 Detection Neural Network (COVNet) architecture was introduced by [17]. This is a 3D deep learning architecture to detect COVID-19. This architecture can extract both 2D local and 3D global illustrative features. The Covent architecture is made with a ResNet architecture as the base model. A max-pooling operation was used for the extracted features from all slices. The finishing feature map is connected with a fully connected layer and they used a softmax activation function for the probability score for every type (COVID-19, Community-Acquired Pneumonia (CAP), and non-pneumonia).

COVID-Net architecture is specially adapted for COVID-19 case detection from chest X-Ray images. So obviously it has high architectural diversity and selective long-range connectivity. The massive use of a projection-expansion-projection design pattern in the COVID-Net [18] architecture is also observed. COVID-Net network architecture is incorporated into a heterogeneous mix of convolution layers. The proposed COVID-Net was pre-trained on the ImageNet dataset and then applied to the COVIDx dataset. Applying this architecture, they got accuracy about 93.3% on the COVIDx dataset.

ChexNet is originally a DenseNet-121 type of deep network which is trained on Chest X-ray images introduced by the paper [19]. So, this architecture has been specially designed to diagnose COVID-19.1024-D feature vectors are extracted for the compact classifiers in ChexNet. They used the Softmax activation function to classify COVID-19, Normal, Viral Pneumonia and Bacterial Pneumonia. The number of trainable parameters in this model is 6,955,906.

COVID-CAPS is a capsule-based network architecture invented by [22]. This model has 4 convolutional layers and 3 capsule layers. 3-dimensional chest X-Ray images are the input of this architecture. The primary layer is a convolutional layer, and then batch-normalization is attached. The second layer is also a convolutional layer, followed by a pooling layer. Correspondingly, the third and fourth layers are convolutional, and the fourth layer is reshaped as the first Capsule layer. Three Capsule layers are embedded in the COVID-CAPS to perform the routing. The last Capsule layer contains the classification parameters of the two classes of positive and negative COVID-19. The trainable parameter is 295,488 for this model. Pre-trained COVID-CAPS gave 98.3% accuracy.

Detail-Oriented Capsule Networks (DECAPS) architecture was introduced by the paper [23]. It uses a ResNet with three residual blocks because the base network which outputs 1024 feature maps, followed by a 1×1 convolutional layer with 512 channels and a ReLU non-linear layer. This architecture is trained in CT images. This model obtained an area under the curve (AUC) of 98%.

Besides these, some papers used different types of approaches Like Details Relation Extraction neural network (DRE-Net) [26] which is ResNet-50 on Feature Pyramid Network [FPN] for extracting top K details from each image and an attention module combined to learn the importance of every detail. In the training stage,[21] and [25] employed the least absolute shrinkage and selection operator (LASSO) to traverse the optimal subset of clinical-radiological features to classify. GLCM, HOG, and LBP were used by [24]. Moreover, [20] used commercial off-the-shelf software that detects nodules and small opacities within a 3D lung volume and subsystem.

3. UNet DL Model for Chest CT scans

The paper of Menget al. [6] discusses a standard framework for the discharge of COVID-19 patients from the hospital .research was carried out using a combination of a novel deep learning algorithm and chest CT of COVID-19 patients with respiratory pathogen nucleic acid test results. Pharyngeal swabs were used to gather Respiratory secretions for testing. Subsequently, low dose CT scans of all patients were also collected.A U-Net DL model was employed in the study due to the advantages of lesion detection with a large size variation and pneumonia volume was an important clinical index to evaluate the stage of illness and prognostic. Furthermore, precise pixel-level segmentation was required and U-Net provided a natural choice for its segmentation capability.The average intersection over union is 0.7894. Fifty-seven (21.1%) and 213 (78.9%) patients exhibited normal lung findings and pneumonia, respectively. 54.0% (115/213) involved mild interstitial fibrosis. 18.8% (40/213) had a total volume ratio of lesions to the lung of more than and equal to 50% according to our severity scale and were monitored continuously in hospital, and three cases of which had a positive follow-up nucleic acid test during hospital observation.

4. CNN for Lung CT Classification

Sally et al.[9]paper discuss an Artificial Intelligence-inspired Model for COVID-19 diagnosis and prediction for patient response to treatment AIMDP.The functionalities of the system are performed using two modules namely the Diagnosis Module (DM) and Prediction Module (PM). The study used the TensorFlow framework which is a popular open-source library for DL.The diagnosis module uses a convolutional neural network (CNN) shown in Figure 2and processes CT scans which can be used for the identification of positive COVID-19 patients. The prediction module on the other side employs a whale optimization algorithm[10] and can predict the treatment response-ability of the patient based on different factors such as the stage of infection, organ failure, and procedure of treatment. The major phases in the proposed model are pre-processing, segmentation, feature selection; classification, prediction, and diagnosis recommendation phase. The diagnosis and prediction modules performed well over a dataset having a large number of CT images and data. The results obtained from the

AIMDP coupled with the implementation of FSWOA with CNN has been compared with the performance of popular diagnostic models.

5. CNN based transfer learning for automatic detection of COVID-19 from X-Ray images.

The paper by Ioannis D. Apostolopoulos et al[11]. uses the technique called transfer learning for automatic detection of the COVID-19 disease. The advantages of transfer learning is that it provides better results for detection of abnormalities in medical image datasets They have acquired datasets of X-ray images having a manifestation of bacterial pneumonia, confirmed COVID-19, and normal cases. They have made an effort to study the performance of popular convolutional neural network architectures for medical image classification. A total of two datasets were utilized for the study purpose.

The convolutional neural network architectures used for the study in this paper were VGG19, MobileNet v2, Inception, Xception, Inception ResNet v2.A parameter called layer cut-off was defined after several experiments which are defined as the number of un-trainable layers beginning from the bottom of CNN.Remaining upper-level layers closer to the output were made trainable and thus were able to extract meaningful information being supplied from the other convolutional layers of the network

Another parameter called the neural network which can be explained by the total number of hidden layers and the number of nodes was used as a classifier at top of the CNN for classification of extracted features. Also, all convolutional layers were activated by the Rectified Linear Unit (ReLU) function.The CNNs were then compiled usinga well-known optimization method called Adam. The training was conducted for ten epochs, with a batch size of 64.

The results from the study conclude that t Deep Learning with X-ray imaging can successfully find out the significant biomarkers about the Covid-19 disease, while the best accuracy, sensitivity, and specificity obtained was 96.78%, 98.66%, and 96.46% respectively.

6. DarkCovidNet model for automatic COVID-19 detection using X-ray images.

Tulin et al. [12] have performed a study for automatic COVID-19 detection using X-ray images which uses a proposed model for binary classification and multi-class classification that can accurately detect whether an X-ray image belongs to a non-COVID-19, COVID-19 or a pneumonia patient. They have suggested that their model can be used by radiologists for validating the initial screening of patients for COVID-19 and pneumonia diseases.

They have used a DarkNet-19 model calledDarkCovidNet model as a classifier that can be used as the basis for a real-time object detection system named YOLO (You only look once).in the proposed approach fewer layers and filters were used in comparison to the originalDarkNet architectures. They have used 80% of X-ray images for training and 20% for validation.The model proposed in the study uses 17 convolution layers with filters being applied to each layer.

Every layer in the DarkNet uses a convolution layer.Two operations are then carried out. Batch normalization is used to enhance the stability of the model and also reduces the training time. LeakyReLU is then subsequently applied to prevent dying of neurons. It is a variant of the ReLU operation used in CNN models.The DarkCovidNet model was trained to categorize the input X-ray images into one of the following COVID-1, No-Findings, Pneumonia. Again, the model was trained to detect two classes: COVID-19 and No-Findings. The researchers obtained a classification accuracy of 98.08% for binary classes and 87.02% for multi-class cases.

7. Weakly-supervised deep learning using 3D CT volumes to detect COVID-19.

The proposed model by Chuansheng Zheng et al[13] employs deep learning-based weakly-supervised a system using 3D CT volumes to detect COVID-19.Chest CT scan images were obtained from picture archiving and communication system (PACS) of radiology department (Union Hospital, Tongji Medical College, Huazhong University of Science and Technology) for the study.

Initially,the lung region for each patient was segmented using a pre-trained UNet and then the segmented region as input to a 3D deep neural network for predicting the manifestation of the COVID-19 disease. The model proposed in the study was called DeCoVNet is a3D deep convolutional neural network which takes a CT volume and its 3D mask as input a pre-trained UNet model was used in the generation of the 3D lung mask.

The proposed model has been divided into three stages. The network stem is the first stage which consists of a vanilla 3D convolution, Batch norm, and a pooling layer. The next stage consists of two 3D residual blocks wherein a 3D feature map was passed into both a 3D convolution with a batch norm layer and a shortcut connection. The final stage was a progressive classifier that progressively abstracts the information in the CT volumes by 3D max-pooling and finally directly outputs the probabilities of being COVID-positive and COVID-negative.

The proposed algorithm obtained 0.959 ROC AUC and 0.976 PR AUC. From the study, a 0.907 sensitivity and 0.911 specificity in the ROC curve was obtained. The researchers conclude that their proposed deep learning model can effectively predict the probability of occurrence of COVID-19 disease through chest CT images.

8. Conclusions

ML techniques are used to accurately predict the manifestation of COVID-19 disease and can prove to be useful for radiologists for validating the results of clinical diagnosis. Medical imaging coupled DL holds great promise in the detection and follow-up of the COVID-19 disease due to the enhanced accuracy in the results of the experiments performed by the researchers. The imaging techniques along with AI can also be employed for classification and positive confirmation of COVID-19 from also a large number of cases analyzed in a short period. Techniques such as DLhave enabled the effective management of COVID-19 patients. AI-based solutions can be used to simultaneously analyze multiple input Computed Tomography (CT) images of the chest may lead to early detection of the disease efficiently. Convolutional neural networks can also be used accurately for COVID-19 classification from X-ray images.

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