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Novel Corona Virus Disease Detection Using an Optimized Convolutional Neural Network

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ABSTRACT

Coronavirus disease 2019 also known as COVID-19 has become a pandemic. The novel coronavirus is an infectious acute disease and can cause respiratory failure. This disease was first recognized in Wuhan, PRC, as a pneumonia outbreak having no specific reasons in late December 2019. This disease is caused by a beta coronavirus called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). The severity of the disease can be understood by the massive number of deaths and affected patients globally. If the diagnosis is fast-paced, the disease can be controlled in a better manner. Laboratory tests are available for diagnosis, but they are bounded by available testing kits and time. The use of radiological examinations that comprise Computed Tomography (CT) can be used for the diagnosis of the disease. Specifically, chest X-Ray images can be analysed to identify the presence of COVID-19 in a patient. The proposed system is implemented with ADECOCNN (an optimized Convolutional Neural Network model) to divide infected and not infected patients. CNN extracts features from image efficiently and its hierarchical structure makes it dynamic in dealing with images. Such layers are logically arranged in three dimensions: depth, width, and height. In such a representation, neurons of a layer are attached to the neurons of the next layer in a limited way. Finally, in the output layer, this number diminishes to score with a single vector probability. Extracted features from preprocessed CT scan images are used to correct the classification of COVID +ve and COVID –ve cases.

Index Terms—Diagnostic Imaging, Deep Learning, Computed Tomography (CT) images, COVID-19, CNN.

I. INTRODUCTION

CORONAVIRUS disease 2019, or COVID-19, is an epidemic disease caused by the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). It outbreaks around the world in a short period and has caused

1,914,916 confirmed cases and 123,010 confirmed deaths as of April 15th, 2020. COVID-19 pushes the health systems of over 200 countries to the brink of collapse due to the lack of medical supplies and staff and thus has been declared as a pandemic by the World Health Organization. The current main diagnostic tool for COVID-19 is via the Reverse Transcription Polymerase Chain Reaction (RT-PCR) test. However, the sensitivity of the RT-PCR test is not high enough to effectively prevent the pandemic. So the false-negative cases of RT-PCR tests are a potential threat to public wellness, and missing any COVID-19 cases will probably cause secondary infections of large areas. To hinder the terrific infection of COVID-19, medical radiology imaging is employed as a complementary tool for the RT-PCR test. This is based on the fact that the clinical signs of chest X-rays for most COVID-19 patients indicate lung infection. The works that CT scan tests are with high sensitivity. Besides, a CT scan test is necessary for monitoring the severity of the illness. However, the diagnosis duration is the major limitation of CT scan tests: even experienced radiologists need about 21.5 minutes to analyze the test results of each case. The experienced radiologists are severely lack during the pandemic outbreak, posting difficulties identifying potentially infected patients in time. Thus, automatic diagnosis systems are highly desired. Thanks to the powerful discriminative ability of deep convolutional neural networks (CNNs), artificial intelligence (AI) technologies are reforming the medical imaging community. Deep CNNs are usually trained on large scale datasets to demonstrate their capability. However, most of the existing CT scan datasets for COVID-19 could not meet this demand, as they contain at most hundreds of CT images from tens of cases. Besides, most of the current COVID-19 datasets only provide the patient-level labels (i.e., class labels) indicating whether the person is infected and lacks fine-grained pixel-level annotations. Thus, CNN models trained with these datasets usually neglect the valuable information for explaining the final predictions.

In recent times, lot of deep learning schemes dealt with theCOVID-19 infection detection via radiographic images The anomaly detection method was proposed for assistingthe radiologist in analyzing a huge number of chest X-rays by Zhang et al. [11]. CT images have been used to separateCOVID-19 from other lung diseases with the help of a deeplearning model by Li et al. [12]. COVID-19 infection detection, using CT images with a high sensitivity and accuracy, is still a challenging job due to the variation in size, position,and texture of infections. In order to address the above-mentioned aspects, an optimized CNN architecture has been designed to help (andautomate) the detection of COVID-19 infections.

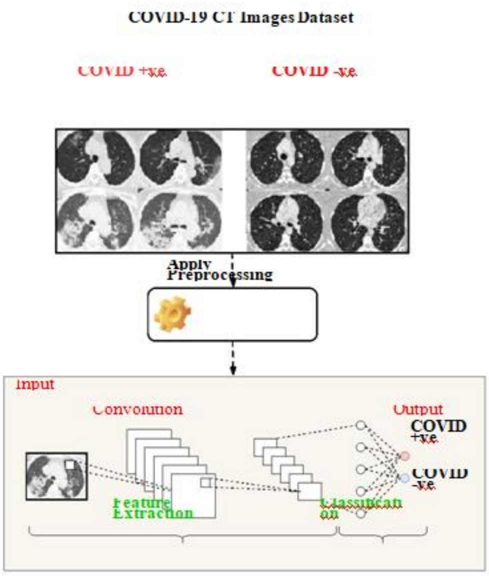


Fig. 1: ADECO-CNN architecture to detect coronavirus disease.

The following steps are used for segmentation and accurate edge detection to contrast any normal tissues and infected tissues. Forthe performance evaluation of the proposed model Automatic Detection of novel Coronavirus disease from CT images using Optimized Convolutional Neural Network) method, an open dataset containing CT images belonging to COVID-19 patients has been used. By considering specificity and sensitivity, the ADECO-CNN novel deep learning-based model takes advantages of the CNN architecture to classify the preprocessed CT images. A sample sketch diagram of the ADECO-CNN methodology is shown in Fig. 1.

A. Contribution and Organization of the Paper

The major improvements introduced by this study are listed below:

- Techniques are introduced to make detection of COVID-19 infection faster by analysis of CT images.
- Four steps image normalization approach is formulated to eliminate noise from lung images and to improve image quality.
- ADECO-CNN optimized CNN model is compared with the reference models (namely GoogleNet, VGG19, and ResNet). Such comparison has been performed with and without applying image normalization technique.
- ADECO-CNN in combination with image normalization technique clas sifies patients into COVID +ve and COVID –ve cases with 99.99% accuracy.

II. RELATED WORK

Recently, image patterns such as chest radiographs and chest CTs are being used for COVID-19 detection [12]. Cohen et al. [13] provided a dataset based on the COVID-19 public image collection of X-rays and CT scans. They extracted more than 125 images from online websites and publications. They further augmented images and used four pre-trained CNN models (ResNet18, AlesNet, SqueezNet, and DenseNet201) for the categorization of COVID-19 cases using X-rays. SqueezNet achieved the highest result with 98% accuracy and 96% sensitivity. Bernheim et al. [14] explored the relationship between symptom onset and chest CT images. They found that imaging patterns not only help in understanding the pathophysiology of the infection but also in the prediction of complication development. Convolution based deep learning schemes have been extensively utilized in studies involving medical images [15].

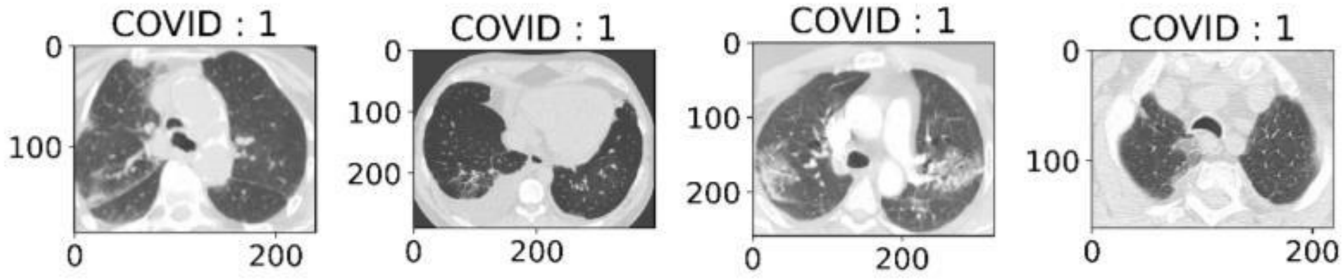
IOT based architecture for big data analysis was proposed by [16] and evaluation of GSCM by [17]. Huang et al. [18] adopted deep deterministic policy gradient to optimize resource allocation. They also proved the effectiveness of performance aware resource allocation scheme. Chang et al. [19] simulated medical images by fusion algorithm. They applied computational intelligence for an efficient and effective healthcare system.

Segmentation facilitates the evaluation of radiological images and used as a preprocessing step to get the region of interest (ROI) that is a lesion or infected region.

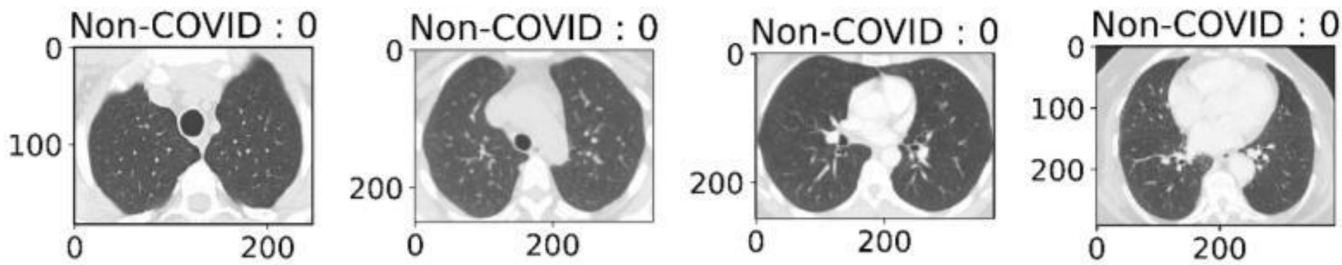
Many researchers have applied different modified transfer learning approaches to facilitate COVID-19 detection purposes. Wang et al. [24] used modified transfer learning method that relies on a CNN based model (M-inception) that was previously trained and studied the changes that can be seen within the CT images of patients that are infected by COVID-19.

The accuracy achieved using a deep learning-based prediction method was 89%. They used 453 CT images belonging to patients that were reported to be COVID-19 positive along with viral aggressive pneumonia cases.

They achieved 83% classification accuracy by combining the AdaBoost and Decision tree. Narin et al. [25] adopted a transfer learning scheme for processing X-ray chest images when dealing with the diagnosis of COVID-19 infected patients. The authors adopted three different models: the Inception ResNetV2,ResNet50 and InceptionV3.



(a) COVID +ve Images



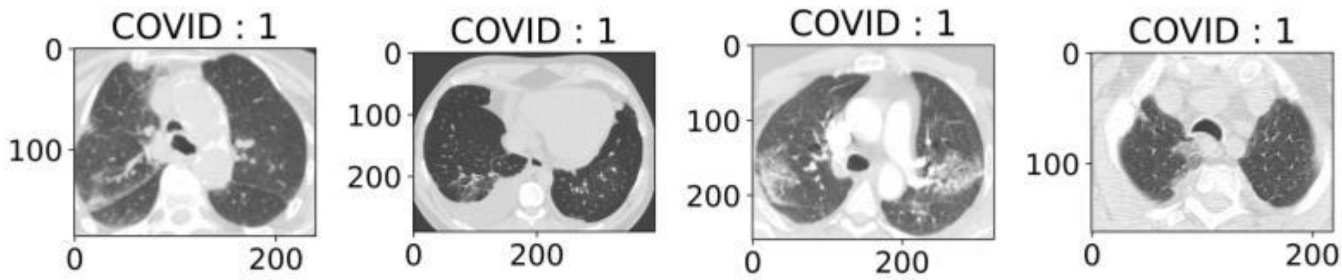
(b) COVID –ve Images

Fig. 3: CT images of COVID +ve and COVID –ve cases.

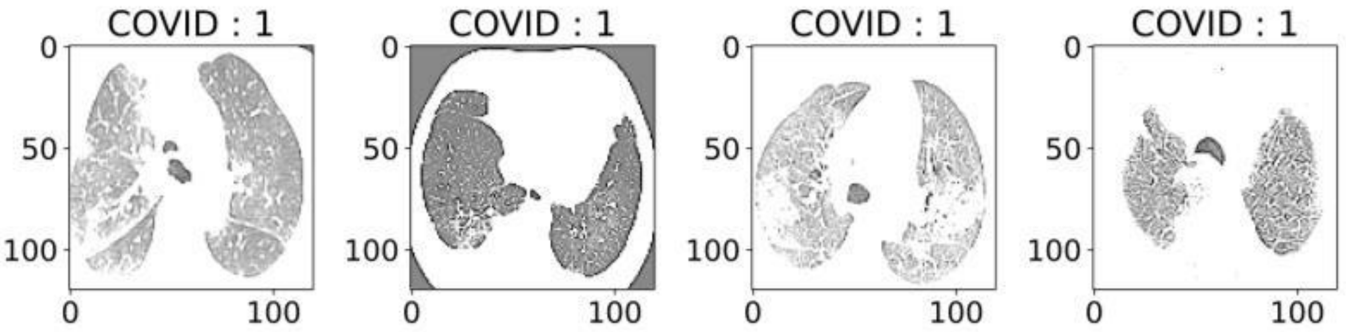
III. MATERIAL

A. COVID-19 Chest CT Images Dataset

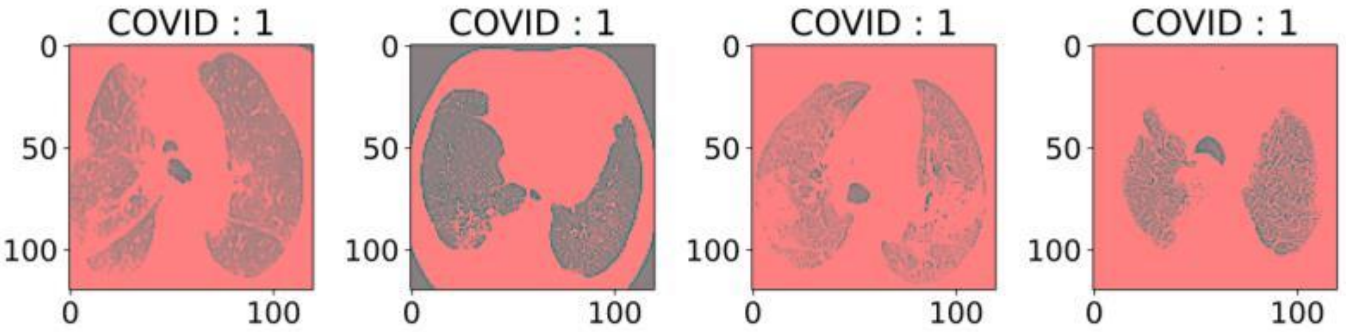
The data-source [26] used in the experiment is available at https://www.kaggle.com/plameneduardo/sarscov2-ctscan-dataset. SARS-COV-2 CT-Scan Dataset comprises of CT images belonging to several patients. It has 1252 CT images belonging to patients that were positive to SARS-CoV-2 (referred as COVID +ve) and 1230 CT images belonging to patients that were not infected (referred as COVID –ve). The entire dataset contains 2482 CT scans in total.



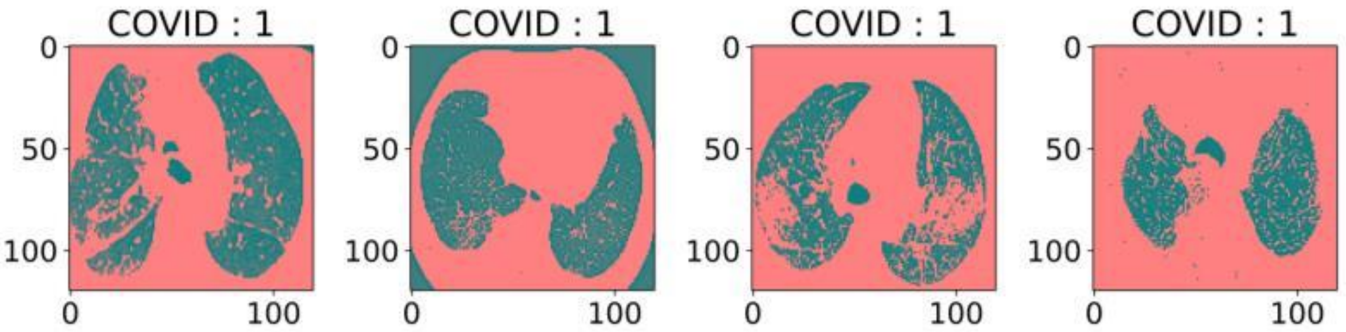
(a) CT scan images without preprocessing



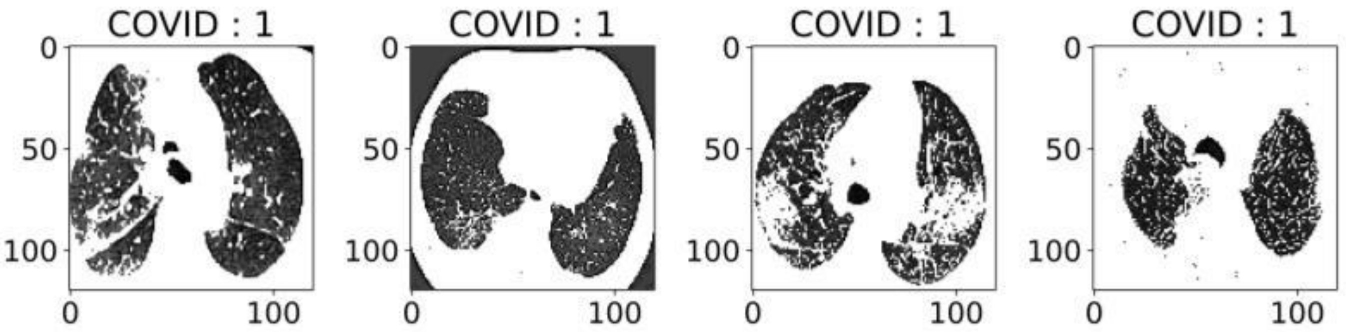
(b) Detection of edges



(c) BGR-image to YUV-image Conversion



(d) Equalization of image intensity



(e) YUV-image to BGR-image conversion

Fig. 4: Four steps of preprocessing.

patches in the lungs are shown in Fig. 3(a) and COVID–ve cases having no infection are shown in Fig. 3(b). The above-mentioned dataset was composed of images taken from patients in hospitals in the Brazilian metropolitan area of Sao Paulo. The main idea behind this dataset was to foster researchers in setting up and tuning appropriate AI algorithms aimed at discerning whether an individual has been infected by COVID-19 or not just by looking at the CT images coming from them.

This section discusses the preprocessing steps used in the experiments and proposes an optimized CNN model to classify CT chest images with the aim of identifying infected patients. The introduced model shows robust results when classifying COVID-19 infected patients.

IV. METHODS

A. CT Images Preprocessing

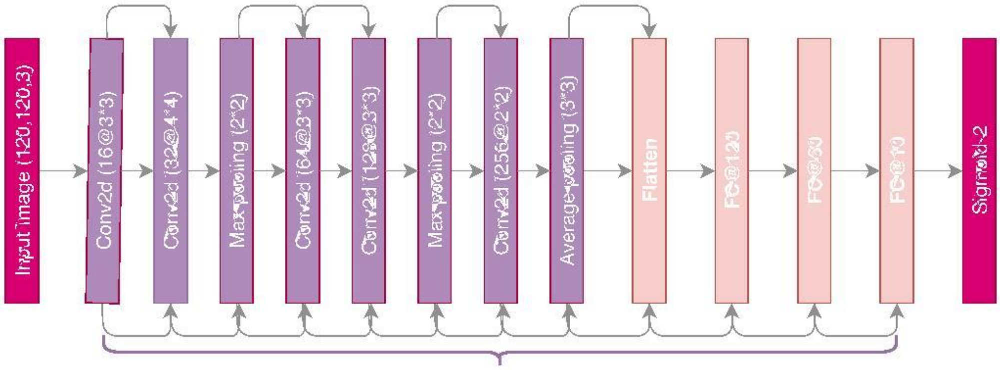
Since the features directly derived from CT images showed different intensities and gray-scales, it is necessary to apply a data preprocessing prior that such images were given as input to the classifier. Data preprocessing strategies involve standardization and normalization.

1) All the CT images were of different intensity and sizes as shown in Fig. 4(a). In the first step, all images have been converted into a fixed size by reducing the dimensions to $120 \times 120 \times 3$ before training as shown in Fig. 4(b).
2) Secondly a filter with values ([0,-1,0],[-1,6,-1],[0,-1,0]) is applied for edge detection. Images with edges can be seen in Fig. 4(c).
3) Then at the third step, values of the luma component is extracted by converting the RGB image to YUV. Luminance is more important than color, so the resolution of U (blue projection) and V (red projection) is reduced but Y is kept at full resolution as shown in Fig. 4(d).
4) Then at the last step, the intensity values are equalized by converting the YUV image back to RGB by smoothing edges and histogram equalization as shown in Fig. 4(e).

B. ADECO-CNN Optimized CNN Model

Convolutional Neural Network (usually referred to CNN) has been widely extensively adopted in several tasks of image classification and is considered a very powerful tool. It has attracted considerable attention in a variety of domains such as image recognition, image analysis, object detection, and computer vision tasks. CNN extracts features from image efficiently and its hierarchical structure makes it dynamic in dealing with images. Such layers are logically arranged in three dimensions: depth, width, and height. In such a representation, neurons of a layer are attached to the neurons of the next layer in a limited way. Finally, in the output layer, this number diminishes to score with a single vector probability.

Extracted features from preprocessed CT scan images are used to correct the classification of COVID +ve and COVID –ve cases. The architectural design of the ADECO-CNN is illustrated in Fig. 5. Predominantly this model involves the below steps:



Activation=ReLU

Fig. 5: Architectural diagram of ADECO-CNN model.

1. pooling. After each convolution step, a new "convolved" image is produced containing features extracted from the previous step. Let an image be represented as I(x, y) and f(x, y) represents the filter that is used. Here is adopted the Rectified Linear Unit (ReLu) as an activation function that is adopted as a complex feature mapping connecting output and input of each layer. The ReLu is a linear function providing positive input values directly or returning a zero value.
2. Classification: Flatten layer converts the data into one dimensional array by creating a single long feature vector and feeding it to the dense fully connected layer. Dense layers carry out a classification by utilizing extracted features of an image obtained from convolutional layers. Usually, the dropout layer with the help of the activation function reduces the feature map and minimizes overfitting. Different weights are associated with fully connected layers in every row and need computational capabilities accordingly. Fig. 5 represents Some common hyper parameters are shared by all the CNN models such as Rectified Linear Unit (ReLU) for activation, Dropout Layer to prevent over fitting and Adam optimizer for optimization. The general architecture of the networks is different among transfer learning models.

V. CONCLUSION

The paper proposes a novel classification model, that can be very useful in predicting the COVID-19 disease, by just analyzing chest CT images. Initially chest CT images from the COVID-19 dataset are normalized upon having applied four preprocessing phases. After that the dataset of CT-images is split into two different parts: a test set and a training one. The training set is then utilized to classify COVID-19 infected patients and to build a model. Furthermore, 5 – fold cross- validation has been conducted to avoid overfitting and ensure generalizability.

To further validate the proposal, the ADECO-CNN approach is related to the existing transfer learning models namely VGG19, GoogleNet, and ResNet. Those models are considered the state of the art by the scientific community. Extensive experiments proved that the ADECO-CNN optimized CNN outperforms the other models in accuracy, sensitivity, precision, and specificity. Therefore, the ADECO- CNN approach is the best among any other COVID-19 disease prediction method and can be implemented in real-time disease classification from chest CT images at any place to control the early outbreak of the disease.

Moreover, there is the need to develop models capable of differentiating COVID-19 cases by additional similar diseases like pneumonia. Besides this medical imaging, other risk factors for the onset of the disease should be considered for a more holistic approach.

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