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DETECTION OF COVID-19 IN CT IMAGES USING DEEP LEARNING

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***Abstract*-The detection of severe acute respiratory syndrome coronavirus (SARS Cov2), which is responsible for corona virus disease (COVID-19) using chest CT is of important in saving life of the patients who are affected by this deadly disease. There number of COVID-19 test kits are in demand in hospitals due to the increasing cases daily. Therefore, it is necessary to implement a detection system as a quick alternative diagnosis option to prevent COVID-19 spreading among people. The conventional RT-PCR test which is used to detect the COVID-19 from throat swabs have potential threat of spreading the disease to health workers. Also, detection in the early stage of COVID-19 is difficult. Early prediction of COVID-19 patients is vital to prevent the spread of the disease to other people. To overcome this difficulty, we aimed to present the use of deep learning for the earlier detection of COVID-19 using chest CT images. Publicly available CT images of 30 COVID-19 and 70 non COVID-19 images are used in our experiment. Three experiments are performed by using convolutional neural network (CNN). The mean accuracy of 99.9047% and error of 0.0953 are obtained from our project. A CNN with preprocessing techniques such as sharpening and Laplacian filtering are used to detect the earlier stage of COVID-19 from CT images. A convolutional neural network with pre-processing and with minimized layers is capable of detecting COVID-19 and in imbalanced CT images.**

***Keywords* – CT images – RT PCR – artificial intelligence - deep learning – Digital Image processing - convolutional neural network – image enhancement – Laplacian filter – Image sharpening – MATLAB**

I. INTRODUCTION

Chest CT (Computed Tomography) has a potential role in the diagnosis, detection of complications, and prognostication of corona virus disease 2019 (COVID-19). Implementation of appropriate precautionary safety measures, chest CT protocol optimization, and a standardized reporting system based on the pulmonary findings in this disease will enhance the clinical utility of chest CT. However, chest CT examinations may lead to both false-negative and false-positive results. Furthermore, the added value of chest CT in diagnostic decision making is dependent on several dynamic variables, most notably available resources (real-time reverse transcription–polymerase chain reaction [RT-PCR] tests, personal protective equipment, CT scanners, hospital and radiology personnel availability, and isolation room capacity) and the prevalence of both COVID-19 and other diseases with overlapping manifestations at chest CT. Chest CT is valuable to detect both alternative diagnoses and complications of COVID-19 (acute respiratory distress syndrome, pulmonary embolism, and heart failure), while its role for prognostication requires further investigation. The authors describe imaging and managing care of patients with COVID-19, with topics including *(a)* chest CT protocol, *(b)* chest CT findings of COVID-19 and its complications, *(c)* the diagnostic accuracy of chest CT and its role in diagnostic decision making and prognostication, and *(d)* reporting and communicating chest CT findings.

CTimaging may offer better sensitivity thanRT-PCR Testing for Corona virus "Early diagnosis of COVID-19 is crucial for disease treatment and control.ComparedtoRT-PCR, chest CT imaging may be a more reliable, practical and rapid method to diagnose and assess COVID-19, especially in the epidemic area".

Artificial Intelligence is an upcoming and useful tool to identify early infections due to corona virus and also helps in monitoring the condition of the infected patients. It can significantly improve treatment consistency and decision making by developing useful algorithms. AI is not only helpful in the treatment of COVID-19 infected patients but also for their proper health monitoring. It can track the crisis of COVID-19 at different scales such as medical, molecular and epidemiological applications. It is also helpful to facilitate the research on this virus using analyzing the available data. AI can help in developing proper treatment regimens, prevention strategies, drugs and vaccine development.

Deep learning is the most successful technique of machine learning, which provides useful analysis to study a large amount of chest x-ray images that can critically impact on screening of Covid-19. In this work, we have taken the PA view of chest x-ray scans for covid-19 affected patients as well as healthy patients. After cleaning up the images and applying data augmentation, we have used deep learning-based CNN models and compared their performance.

Deep Learning techniques have been on a rise since the last few years and have completely changed the scenario of many research fields. Especially, in medical field, image data set such as retina image, chest CT, chest X-ray, and brain MRI provides promising results with an extended accuracy% by using the deep learning techniques. As we know, CT image gives faster results for scanning of various human organs in the hospitals. The interpretation of various CT images is usually performed manually by an expert radiologist. As a data scientist, if we train those captured images with the significance of deep learning that will be a great aid to medical experts for detecting the COVID-19 patients. This will help the developing countries where the CT facility is available but the availability of an expert is still a dream. To this advantage, we also aim to develop a deep neural network that can analyze the CT images of lungs and detect whether the person tests positive for the virus or not. Among various deep learning classifiers, in particular, the Convolutional Neural Networks (CNN) has been immensely effective in computer vision and medical image analysis tasks. The results of CNN have proven its cogency in mapping of image data to a precise and expected output. Since the lungs are the primary target of the virus, analyzing their changes can give an explicit result of presence of the virus. The main contribution of this research work is to propose a CNN based model, which is able to train the images of corona virus infected lungs and those of healthy lungs. Proposed model is able to detect the COVID-19 cases at a faster speed by detecting the features of infected patients as hazy or shadowy patches in the CT images of lungs.

Digital image processing is the use of computer algorithm to perform image processing on digital images. Digital image processing has many advantages over analog image processing. It allows a much wider range of algorithm to be applied to the input data and can avoid problems such as buildup of noise and signal distortion during processing since images are defined over two-dimension digital image processing may be modeled in the form of multidimensional system.

Many of the techniques of digital image processing or digital picture processing as it often was called were developed in the 1960. The cost of processing was fairly high, however, with the computing equipment of that era. That changed in the 1970s, when digital image processing proliferated as cheaper computers and dedicated hardware become available image then could be processed in real time, for some dedicated problems such as tale purpose computers become faster, they started to take over the role of dedicated hardware for all but the most specialized and computer intensive operations.

In medicine, many techniques are used such as segmentation and texture analysis, which is used for find out many disease and disorder identifications. Convolutional neural network methods are widely used now a day especially in new modalities such as PET-CT and PET-MRI. In the field of bioinformatics, telemedicine and format less compression techniques are used to communicate the image remotely.

Convolutional neural networks (CNN) can be used for the creation of a computational model that works on the unstructured image inputs and converts them to corresponding classification output labels. They belong to the category of multi-layer neural networks which can be trained to learn the required features for classification purposes. They require less preprocessing in comparison to traditional approaches and perform automatic feature extraction which gives better performance.

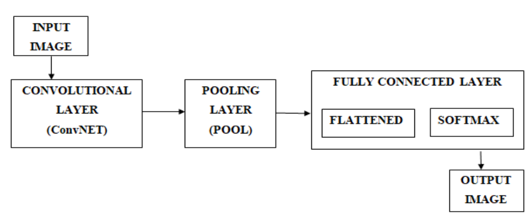

Fig 1BLOCK DIAGRAM OF CNN

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II. PROBLEM DEFINITION

A. Open Problem

An initial stage of COVID-19, RT-PCR and chest CT had similar and good diagnostic performance in rapid screening of clinically suspected COVID-19 patients outside the epidemic center. A radiologist with proper training can differentiate COVID-19 with other common pathogen induced pneumonia in clinical setting. Normal chest CT can be found in RT-PCR positive COVID-19 cases, and typical CT manifestations can be found in RT-PCR negative cases. To compensate potential risk of false-negative in initial screening RT-PCR, chest CT should be applied for clinically suspected COVID-19 patients with negative initial RT-PCR.

B.Computed Tomography

A CT scan or computed tomography scan (formerly known as a computed axial tomography or CAT scan) is a medical imaging technique that uses computer-processed combinations of multiple X-ray measurements taken from different angles to produce tomographic (cross-sectional) images (virtual "slices") of a body, allowing the user to see inside the body without cutting. The personnel that perform CT scans are called radiographers or radiologic technologists.

Use of CT scans has increased dramatically over the last two decades in many countries. An estimated 72 million scans were performed in the United States in 2007 and more than 80 million in 2015.

C. CT Image Acquisition and Analysis

Right after the swab sampling, non-contrast high resolution CT thorax images were acquired with 1-mm slice thickness following acquisition parameters of usual protocol and reformatted with soft tissue and lung windows. All images were transferred to a stand-alone workstation for analysis. Typical chest CT findings were extracted from previously published reports and served as diagnostic reference including: ground-glass opacification with or without consolidation, crazy paving patten, peripheral and diffuse distribution, and bilateral/multilocular involvement. Two experienced general radiologists (LJX and LZD, 17 and 14 years of experience), who had specific training of COVID-19 presentation on chest CT by online courses and real-life cases, independently reviewed the images to determine whether CT findings were positive. Image readers were aware of the patients' epidemiological history and clinical characteristic, but blind to personal information and RT-PCR results, which is the same as clinical setting. At first, their own results were recorded for inter-observer reliability test. Then the final CT results were determined by their consensus discussion for diagnostic performance analysis.

To compensate potential false negative of initial RT-PCR, a screening strategy by combing initial RT-PCR and CT was once advocated in Hubei province (Wuhan is the provincial capital). Patients were confirmed as COVID-19 when initial RT-PCR was positive or initial RT-PCR negative but CT positive. When initial RT-PCR and CT were negative, follow up procedure was provided to the patient. We also analyzed our data to explore the diagnostic value of this strategy. To compare the performance of chest computed tomography (CT) scan versus reverse transcription polymerase chain reaction (RT-PCR) in the initial diagnostic assessment of coronavirus disease 2019 (COVID-19) patients.

D. Advantages of CT Over RT-PCR

A systematic review and meta-analysis were performed as per the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. A search of electronic information was conducted to identify studies comparing the diagnostic performance within the same patient cohort of chest CT scan versus RT-PCR in COVID-19 suspected cases. Sensitivity, specificity and accuracy were primary outcome measures. Secondary outcomes included other test performance characteristics, discrepant findings between both investigations and main chest CT findings.To compare the performance of chest computed tomography (CT) scan versus reverse transcription polymerase chain reaction (RT-PCR) in the initial diagnostic assessment of coronavirus disease 2019 (COVID-19) patients. To overcome this, CT is used here for diagnosis the COVID 19 because, its sensitivity and accuracy is high. Due to high sensitivity and accuracy, the earlier stage of COVID-19 is easily diagnosis.

E. Need for Present Work

CNN tends to be a more powerful and accurate way of solving classification problems. ANN is still dominant for problems where datasets are limited and image inputs are not necessary. Because of CNN's ability to view images as data, it's the most prevalent solution for computer vision and image-dependent machine learning problems.

Using ANN, image classification problems become difficult because 2 dimensional images need to be converted to 1 dimensional vector. This increases the number of trainable parameters exponentially. Increasing trainable parameters takes storage and processing capability. In other words, it would be expensive. The main advantage of CNN compared to its predecessors is that it automatically detects the important features without any human supervision. This is why CNN would be an ideal solution to computer vision and image classification problem.

III. PROPOSED SYSTEM

A. Project Description

The entire theme of the project is to detect the covid 19 disease using CT images by applying digital image processing technique such as convolutional neutral network at deep learning. COVID-19 applications solely through the lens of Deep Learning. In our project, we propose then use of chest CT scan over X-ray scan of lungs, considering the latter's required diagnostic time. A X-ray scan of then lungs takes significantly more time than a CT scan does, and this means more contact duration with suspected or confirmed COVID-19 patients. Several categorized experiments were performed to evaluate the efficiency of the ConvNet on the considered image database and to compare ConvNet with other models using the basic statistical characteristics of the images, which can provide effective information for classification. ConvNet Experiments: ConvNet experiments were performed on two subcategories: COVID-19 or NON COVID-19. It included the use of four different network architectures with varying numbers of convolutional and fully connected layers, and basic image pre-processing techniques to test the results using various structures and pre-processing methods.

In comparison with other surveys on COVID-19 applications in Data Science or Machine Learning, we provide extensive background on Deep Learning. Also we provide a detailed analysis of how the given data is inputted to a deep neural network and how learning tasks are constructed.

B. Architecture of CNN for the Detection Of Covid-19

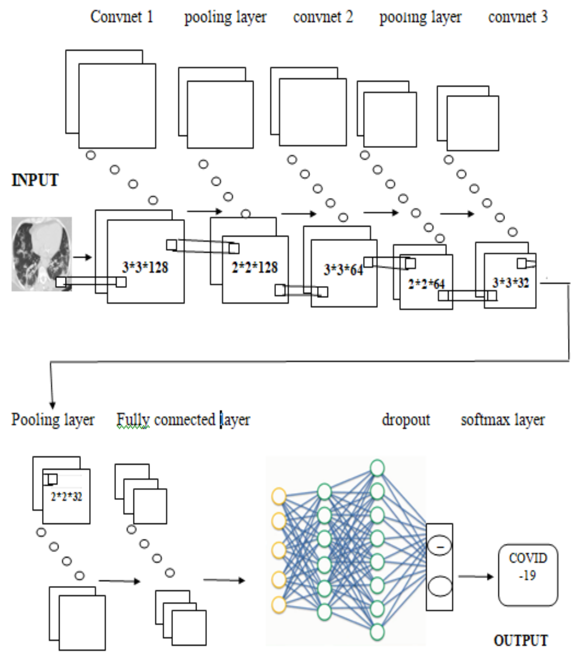

Fig 2. Architecture of CNN to Detect COVID-19

C. Application of CNN to Detect Covid-19

In this project, we have proposed a deep learning neural network-based method ConvNet, an alternative fast screening method that can be used for detecting the COVID-19by analyzing the CT patients. Convolutional layer applies convolution operation for extraction of features. With the increase in depth, the complexity of the extracted feature decrease. The size of the convolutional layer matrices is fixed to 3*3 whereas number of filters is decrease progressively as we move from one block to another. The number of filters is 128 in the first convolutional block while it is decreased to 64 in the second and 32 in the third. This decrease in the number of filters in necessary to compensate for the reduction in the size of the feature maps caused by the use of pooling layers in each of the blocks. Convolutional Layer is followed by a Pooling Layer. The primary aim of this layer is to decrease the size of the convolved feature map to reduce the computational costs. This is performed by decreasing the connections between layers and independently operates on each feature map. Depending upon method used, there are several types of pooling operations. In this architecture, we use average Pooling of size 2*2, it calculates the average of the elements in a predefined sized Image

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section. The total sum of the elements in the predefined section is computed in Sum Pooling. The Pooling Layer usually serves as a bridge between the Convolutional layer and fully connected layer. Finally, in fully connected layer, one of the most important parameters of the CNN model is the activation function. They are used to learn and approximate any kind of continuous and complex relationship between variables of the network. In simple words, it decides which information of the model should fire in the forward direction and which ones should not at the end of the network. It adds non-linearity to the network. There are several commonly used activation functions such as the ReLU and SoftMax. Each of these functions has a specific usage. For a binary classification CNN model SoftMax functions are preferred for a multi-class classification, generally SoftMax is used. When the SoftMax layer classifies whether the input lung CT image is either COVID-19 or NON-COVID-19.

IV. DATA SET ANALYSIS

A. Data Acquisition

The CT images have been taken from the internet. Images for our project were downloaded in the Kaggle website. The acquired data set consist of around 1222 covid and 1199 non covid images. The data set includes images of covid and non-covid CT images of people. Each of the downloaded images belongs to RGB color space by default and stored in uncompressed png format.

B. Data Preprocessing

The enhancement of acquired CT images is necessary because human perception is highly sensitive to edges and fine details of an image, and since they are composed primarily by high frequency components, the visual quality of an image can be enormously degraded if the high frequencies are attenuated or completed removed. In contrast, enhancing the high-frequency components of an image leads to an improvement in the visual quality. Image sharpening refers to any enhancement technique that highlights edges and fine details in an image. So, here we use double enhancement technique to highlight the edges of CT images.

C. Trained Image

It can be a trained only by using know pattern without a mathematical model any input and output. The trained CNN has been mapping ability to learn feature mapping relationship between input data and output data of the convolutional layer and pooling Layer. Training CNN includes two stages: single training and whole model training. The training process of CNN has two stages includes,

1. Forward propagation2. Backward propagation

Forward propagation

Take input from the sample input and put to CNN and calculate correspond output. At this stage, the feature information is extracted from the input layer to the output layer step by step, and the output in the last layer is multiplied by the weight matrix of each layer to obtain the final classification result.

Backward propagation

Calculate the difference between the actual output and the corresponding ideal output and then adjust the weight matrix by inverse propagation.

V. EXPERIMENTAL ANALYSIS

The experimental analysis process co be represented as a spiral of activities, namely experimental discovery, experimental classification and organization, experimental negotiation and experimental documentation.

A. Input Requirement

The input may be healthy lung, pneumonia lung or corona virus affected lung image are given to the CNN by MATLAB. The outputs is taken by the feature extraction method through the classification of the diseases.

B.Output Requirement

The result of CNN classifier strategy for testing samples, these results are obtained using a neural network classification for three different diseases. The output is obtained in the MATLAB platform.

C. Functional Requirement

Convolution neural networks are used in the automatic detection of leaves diseases Convolution neural network is chosen as a classification tool due to its well-known technique as a successful classifier for many real applications The training and validation processes are among the important steps in developing an accurate process model using CNNS The dataset for training and validation processes consists of two parts, the training feature set which are used to train the CNN model, whilst a testing features sets are used to verify the accuracy of the trained CNN model.

D. Resource Requirement

Software requirements is a sub-field of Software engineering that deals with the elicitation, analysis, specification, and validation of requirements for software requirements analysis in systems engineering and software engineering, encompasses those tasks that go into determining the needs or conditions to meet for a new or altered product, taking account of the possibly conflicting requirements of the various stakeholders, such as beneficiaries or users.Requirement analysis is critical to the success of a development project Requirements must be actionable, measurable, testable, related to identified business needs or opportunities, and defined to a level of detail sufficient for system design.

E. Software Requirement

The minimum hardware requirements for this project are listed in table 1

SOFTWARE	REQUIRMENT
Operating system	Windows 2000 XP
Tool	MATLAB version 2013

Table 1 Software Requirement

VI. IMAGE ENHANCEMENT

Image enhancement is the procedure of improving the quality and information content of original data before processing.The main objective of image enhancement is a processing on an image in order to make it more appropriate for certain applications. Image enhancement mainly sharpens image features such as boundaries, edges or contrast and reduces the ringing artifacts. In our project, we use three technique to enhance the original image are

- Sharpening
- Laplacian filter
- Double enhancement

SHARPENING

Sharpening an image increases the contrast between bright and dark regions to bring out features.

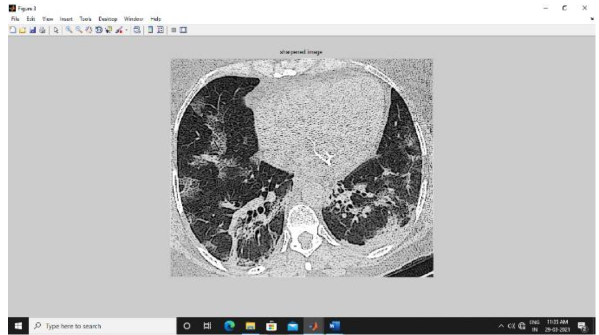

Fig 3 Sharpened Image in Preprocessing

The sharpening process is basically the application of a high pass filter to an image. As mentioned in the filtering section of this chapter, filters can be applied to images in IDL with the CONVOL function. See High Pass Filtering for more information on high pass filters.

LAPLACIAN FILTER

A Laplacian filter is an edge detector used to compute the second derivatives of an image, measuring the rate at which the first derivatives change. This determines if a change in adjacent pixel values is from an edge or continuous progression.

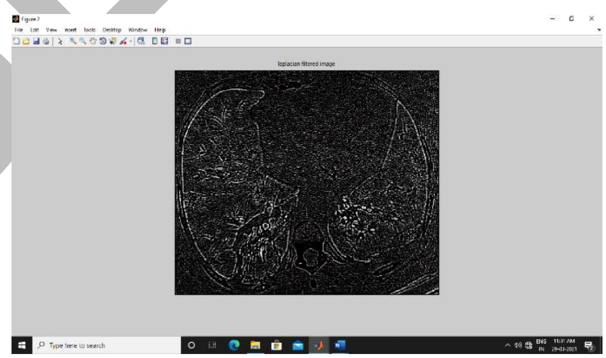

Fig 4 Laplacian filtered image in preprocessing

Laplacian filter kernels usually contain negative values in a cross pattern, centered within the array. The corners are either zero or positive values. The center value can be either negative or positive.

DOUBLE ENHANCEMENT

In Image, double enhancement improves the clarity of images for human viewing. Blur and noise of an image is removed which increase contrast and gives details of an image are examples of double enhancement operations.

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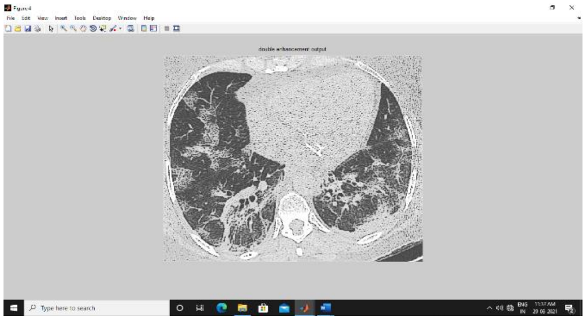

Fig 5. Double Enhancement in Preprocessing

ARCHITECTURAL PROPERTIES OF CONSIDERED ConvNet

ARCHITECTURE NAME	ConvNet LAYER	FILTERS	FILTER SIZE		POOLING AND SIZE	DROPOUT
ConvNet#1	ConvNet Layer 1	128	3x3	5x5	Avg-pooling 2x2	0.2
ConvNet#2	ConvNet Layer 1	128	3x3	5x5	Avg-pooling 2x2	0.2
	ConvNet Layer 2	64	3x3	5x5	Avg-pooling 2x2	0.2
ConvNet#3	ConvNet Layer 1	128	3x3	5x5	Avg-pooling 2x2	0.2
	ConvNet Layer 2	64	3x3	5x5	Avg-pooling 2x2	0.2
	ConvNet Layer 3	32	3x3	5x5	Avg-pooling 2x2	0.2

Table 2

TESTING RESULT:

EXPERIMENT	NO OF IMAGES	MEAN ACCURACY (%)
Exp.1	16	99.5%
Exp.2	16	99.02%
Exp.3	16	99.11%

Table 3

TRAINING RESULT:

EXPERIMENT	NO OF IMAGES	MEAN ACCURACY (%)
Exp.1	25	99.08%
Exp.2	25	99.51%
Exp.3	25	99.32%

The average accuracy = 99.9047

The error obtained = 0.0953

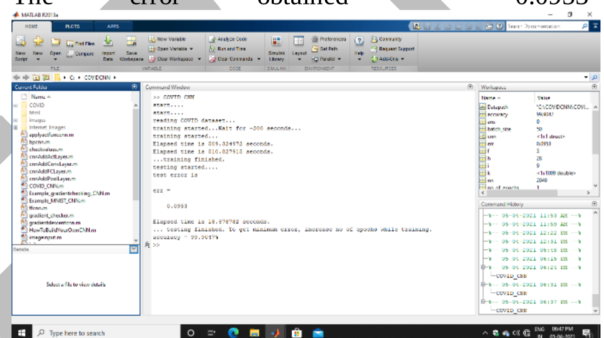

Fig. 6 The output of the detection of COVID-19 in CT images using Deep Learning

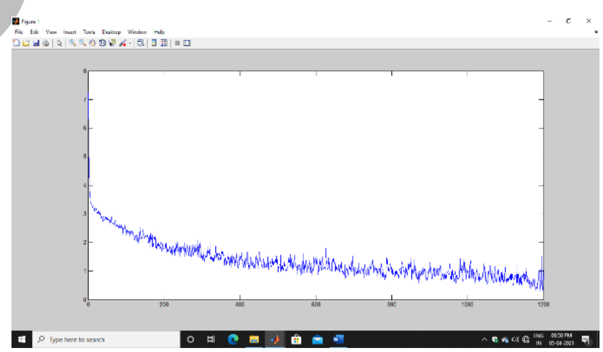

Fig. 7 The graph for the detection of COVID-19 in CT images using Deep Learning.

FUTURE ENHANCEMENT

In this study, we show the potential of Deep Learning models for the task of COVID-19 detection on CT images. As a future research path, we intend to build a very large CT image datasets, in order to try to cover a larger spectrum of equipment (sensors), ethnic groups and acquisition processes and thus, properly validate our method.

In this work, an experimental evaluation of existing Deep CNN based image classification approaches is presented in order to identify COVID-19 positive cases from chest CT scan images. Moreover, a decision fusion-based approach is also proposed, which combines the predictions of each of the individual Deep CNN models, in order to improve the predictive performance. From the extensive experimentations, it is observed that the proposed approach can achieve very impressive result, while having a good reduction of the number of False Positives. From the experimental observations, it is clear that Deep CNN based approaches can potentially have a huge impact on the spread control of COVID19 by providing fast screening. With DL based approaches being used widely in other medical imaging tasks, it is high time for such approaches to be used in the screening process of the current pandemic as well. Furthermore, although the proposed approach shows great promise, there is still quite a bit of room for potentially improving the predictive performance of the approach. Recently, ideas like Transfer Learning, Image Augmentation, and Feature level Fusion have been shown to boost the performance of DL based models drastically. These ideas are to be explored as part of the future.

VII. CONCLUSION

Early prediction of COVID-19 patients is vital to prevent the spread of the disease to other people. In this work, we proposed a deep learning-based approach using CT images Convolutional neural network (CNN) is quite an efficient deep learning algorithm in the medical field since we get an output just by processing the CT scan images to the respective model. The CTnet-10 model had very well classified the images as COVID-19 positive or negative. Our other models have provided us with much better accuracy. Our self-developed model, CTnet-10, took the lowest time for training, testing, and execution. The method used by us is well-organized one that can be used by the doctors for the mass screening of the patients. It will yield better accuracy and at a faster rate as compared to the current RT-PCR method. With the above method for the classification of the CT scan images of the COVID-19 patients, data can be extracted, which would help the doctors to get the information feasibly and quickly.

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