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Review Paper for Detection of COVID-19 from Medical Images and/ or Symptoms of Patient using Machine Learning Approaches

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***Abstract—T*he new type of coronavirus COVID-19 virus was first detected in Wuhan-China. A COVID-19 certified patient is characterized by fever, fatigue, and dry cough. The coronavirus (COVID-19) epidemic is spreading worldwide. In this review paper, a database of X-ray, CT-Scan images from patients with common bacterial pneumonia, confirmed Covid-19 infection, and common cases, were used to automatically detect Coronavirus infection. The purpose of the study was to evaluate the effectiveness of COVID-19 acquisition. During the COVID-19 scenario, the number of infected cases rises in huge number globally. Due to this fact, a vital decision had been taken by medical experts and infected patients to adopt various medical facilities within a reasonable amount of time.**

Keywords*: *COVID-19, X-ray, Deep learning, Artificial intelligence (AI), Healthcare, Machine learning (ML)

I. Introduction

The novel coronavirus known as COVID-19, it is firstly detected in the city of China that is Wuhan. In December 2019, (WHO) the World Health Organization acknowledged that this virus could cause respiratory infections through coughs, flu, and pneumonia. Since then, the virus starts spreading in China and has now spread too many countries around the world. The WHO Emergency Committee on 30th January, 2020 affirmed it an epidemic because of its rapid spread of the individual and most infected people have no immune system.

First, people infected with the COVID-19 novel in central Wuhan city of China had contacts to seafood and the live animal markets, demonstrating the spread of animal to human. After that the increase in the number of infected persons that were not in contact with lives animals, led to the transmission of human-to-human.

Thereafter, on 11th March, 2020 the WHO affirmed the COVID-19 novel epidemic because the number of infected cases achieved 118,000 and higher than 4,000 deaths, and the people became infected on all continents.

The medical applicability of COVID-19 can be observed through various symptoms like cough, nausea and mild-fever. MERS or SARS are one of the categories of COVID-19 [2]. SARS is also a respiratory disease due to (SARS-CoV), which came to known in the year 2003 in Southern part of China and distributed in lots of other regions around the world. In addition, cases of MERS virus were earliest reported in Saudi Arabia and caused 867 of 2494 deaths. According to gene analysis of the virus, the virus evolved from the bats [3]. The medical demonstration of COVID-19 is complex and can be characterized like mild-fever, cough and nausea. There are various ways to detect COVID-19, including Computed Tomography (CT) scan; Nucleic Acid Test (NAT). NAT is used to determine certain sequences of nucleic acids and the species, especially bacteria or viruses that can cause infection in the blood, urine, or tissues. Even though NAT techniques and diagnostic kits are important in identifying corona, CT scan is very beneficial in identifying the size and severity of lung inflammation [4]. China's National Health Commission has approved the submission of a radiographic demonstration of pneumonia for medical symptomatic level in Hubei province [5]. It confirms the importance of CT scan images for the detection of COVID-19 pneumonia seizures.

The WHO has affirmed COVID-19 as an epidemic and a large number of patients spend many hours in waiting for a CT scan image in the hospital. This is not only overcrowding in medical system, it makes patients more frustrated, and also causes higher risk of cross-infection by other patients. In particular, in Hubei province, suspected cases, confirming COVID-19 infected patients and cases under the medical supervision must undergo for CT-Scan of lungs. The infection of the infected lungs is low at the onset of an infected patient of COVID-19. In addition, the radiologists are very less compares with the number of infected patients. The result is that the medical systems are overcrowded. So this is the main problem for late identification and segregation of infected individuals and the ineffective treatment of infected patients [5]. Specifically, In Italy hospitals admitted only the most important infected person, with a shortness of breath and a high fever [6].

In the epidemic of COVID-19, the great need for diagnostics have led companies, experts and researchers to provide superior, smarter and more effective responses. Ping, a company owned by Smart Healthcare, has developed a smart imaging program for the smart CT imaging system of COVID-19, which can analyze the virus in about 15 seconds and give the result with more than 90% accuracy rate [7]. Even both the RT-PCR (Reverse Transcription Polymerase Chain Reaction) and CT scan for COVID-19 identification are defective [7]. Therefore, the most responsible procedure is a combination of various methods. In addition, clinical identification kits are used to identify COVID-19. However, this device is expensive but needs to be installed for identification.

Smartphones of today's era are established with many sensors and hold computing power. One of the key features of smartphones is the ability to capture, collect and store large volume data in suspected or verified cases of COVID-19. Also the smartphone has the ability to scan the images of CT-Scan of a COVID-19 patient for examination intention. In addition, multiple images of CT-Scan of the same infected patient can upload in the smartphone to get a comparative analysis of how the lesions are formed. The examination is very helpful in suspected cases of COVID-19 to identify and detect the level of pneumonia

COVID-19 is especially caused by acute respiratory syndrome coronavirus 2 (SARSCoV2), which extent to that limit where World Health Organization 2020 declared it a pandemic, at the time of writing this review paper, greater than 7.24 million cases reported in India and 38.37 million worldwide. In India, Maharashtra became the epicentre with more than 15, 43, 837 confirmed cases and over 40,701 deaths (Coronavirus Outbreak in India (covid9india.org) 2020). At the peak of the epidemic, medical experts were frustrated, with emergency departments (EDs), and Intensive Care Units (ICUs) expanding beyond capacity and resources. The phenotypes of COVID-19 range from mild or minor symptoms and recurrent recovery to rapid degeneration, acute respiratory distress syndrome (ARDS), systemic failure and death. The trajectory of patients who may have failed to decompose is being investigated but is still difficult at present; a lack of standard of care compels the unprecedented workflow of doctors and nurses. Given the magnitude of these cases and the growing number of cases, there is an urgent need for tools that can expand current health care resources. This theory highlights the benefits of these tools seen in various clinical settings and explains how a number of ML and AI algorithms, when they can be constructed conscientiously, can be added during the COVID-19 epidemic.

II. Search Strategy

In this study, valid databases, including IEEE Xplore, ScienceDirect, SpringerLink, ACM, and ArXiv, have been used to search for Covid-19 papers. Moreover, a more detailed Google Scholar search is employed. The articles are selected using the keywords COVID-19, Corona Virus, Deep Learning, Segmentation, and Detection of COVID-19 from medical images and/ or symptoms of patient using Machine Learning Approaches. The latest selection of papers is done with the mentioned keywords on August 12th, 2020. Figure 2 indicates the number of datasets used for COVID-19 detection and prediction based on the published papers using DL methods.

III. Discussion

In this study, novel coronavirus infection COVID-19 and techniques for the acquisition of COVID-19 are discussed in detail. The main focus of this review paper is to select the best DL models to detect the segment of the lungs, and predict the COVID-19 patients using DL techniques. The summary of works done on classification, segmentation, and prediction are presented in Tables 1 and 2 respectively. Figure 1 depicts the total number of investigations conducted in the field of classification, segmentation, and prediction of COVID-19 using DL models. Figure 2 shows the total number of times each modality is used in reviewed studies. It can be observed that most of the researchers have used X-ray images. Various DL models developed for the automated detection of COVID-19 patients is shown in Figure 3. It can be noted from the figure that; different types of convolutional networks have been commonly used. Also, for the automated segmentation of lungs, various types of U-Net are more common.

Table 1: Summary of Standard Deep Learning Methodologies Used for the Automated Detection of COVID-19 Patients

Work	Dataset	Modalities	Number of Cases	Pre-processing	DNN tool box	DNN	Number of Layers	Classifier	Post Processing	K-Fold	Performance Criteria (%)
[15]	Combination of Different Datasets	X-ray	50 COVID-19, 50 Normal Images	Rescaling	NA	ResNet50	Modified Version	Softmax	NA	5	Acc=98 Recall=96 Spe=100
[16]	Combination of Different Datasets	X-ray, CT-Scan	85 COVID-19 X-ray, 203 COVID-19 CT-scan, 85 Normal X-ray, 153 Normal CT-scan	Cropping, resizing	NA	AlexNet	Modified Version	Softmax	NA	NA	Acc=98 Sen=100 Spe=96
[17]	Cohens Git Hub	X-ray	25 COVID-19, 25 Normal Cases	Rescaling	Keras with Tensor-Flow2 Backend	COVIDX-Net (VGG19, Dense Net 201)	Standard Version	Softmax	NA	NA	Acc=90 Pre=83 F1-Score=91

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[18]	Combination of Different Datasets	X-ray	70 COVID-19 subjects, 1008 Pneumonia Subjects	Rescaling, DA	NA	ResNet-18	Standard Version +8	Sigmoid	Grad-CAM	NA	Sen=96 Spe=70.65 AUC=95.18
[19]	COVIDx	X-ray	266 COVID-19 Patient Cases, 8,066 Normal Patient Cases, 5,538 Non-COVID19 Pneumonia Patient Cases	DA	Keras with Tensor-Flow Backend	COVID-Net	87	Softmax	Explainability-Driven Audit (GSInquire Method)	NA	Acc=93.3 Sen=91 PPV=98.9
[20]	COVIDx	X-ray	76 COVID-19, 1583 Normal, 4290 Pneumonia Cases	DA, RGB format, Normalizing	MATLAB	COVID iagnosis-Net	Standard Version	Decision-Making System	Class Activation Mapping Visualization	NA	Acc=98.3 Spe=99.13 F1-Score=98.3
[21]	Combination of Different Datasets	X-ray	295 COVID-19, 65 Normal, 98 Pneumonia Images	Fuzzy Color Method, Image Stacking Technique	MATLAB	MobileNetV2 SqueezeNet	Standard Version	SMO, SVM	Social Mimic Optimization Method	5	Acc=99.27
[22]	Clinical	CT-Scan	368 COVID-19 Patients, 127 Patients with Other Pneumonia	Segmentation, Rescaling, Multi-view Fusion	Keras	ResNet50	Modified Version	Dense Layer	NA	NA	Acc=76 Sen=81.1 Spe=61.5
[23]	Combination of Different Datasets	0X-ray	1270 COVID-19,15000 No-Findings1 and 500 Pneumonia Images	NA	NA	DarkCovidNet (CNN)	39	Linear	Interpretation of Heatmaps Results of the Dark Covid Net Model by an Expert Radiologist	5	2-classes: Acc=98.08 Spe=95.3 Sen=95.13 Pre=98.03 F1-Score=96.51 3 classes: Acc=87.02 Spe=92.18 Sen=85.35 Pre=89.96 F1-Score=87.37
[24]	Clinical	CT-Scan	108 COVID-19, 86 Non-COVID-19 Patients	Different Methods	NA	ResNet-101, Xception	Standard Version	Softmax	NA	NA	Sen=98.04 Spe=100 Acc=99.02
[25]	Combination of Different Datasets	X-ray	105 COVID-19 ,11 SARS, 80 Normal Samples	DA, Histogram, Feature Extraction using AlexNet, PCA, K-means	MATLAB	DeTraC (ResNet18)	Standard Version	Softmax	Composition Phase	NA	Acc=95.12 Sen=97.91 Spe=91.87
[26]	Combination of Different Datasets	X-ray	0284 Covid-19, 3100 Normal, 3300Pneumonia1Bacterial, 3270Pneumonia1Viral Images	Rescaling	Keras with Tensor-Flow Backend	CoroNet	Modified Version	Softmax	NA	NA	Acc=89.5 Pre=97 F1-Score=98
[27]	Combination of Different Datasets	X-ray	990COVID-19 Cases From1the COVID190Chest X-ray1Dataset, 207 Images From Both Dataset	Balancing dataset, DA	Keras	GSA-DenseNet121-COVID-19	Modified Version	Softmax	NA	NA	Acc=98 Pre=98 F1-Score=98
[28]	Combination of Different Datasets	X-ray	108 COVID-19, 515 Other Pneumonia, 453 Normal	Class Balancing Methods, Binary Thresholding, Adaptive Total Variation Method	NA	NASNetLarge	Modified Version	Softmax	CAM and LIME Techniques	NA	Acc=98 Pre=88 Spe=95 F1-Score=89

TABLE 2: SUMMARY OF DEEP LEARNING TECHNIQUES APPLIED FOR COVID-19 DETECTION

Work	Dataset	Modalities	Number of Cases	Pre-processing	DNN Toolbox	DNN	Number of Layers	Classifier	Post Processing	K-Fold	Performance Criteria (%)
[29]	Combination of Different Datasets	CT-Scan	610 COVID-19 Images, 695 Non-COVID-19 Images	Resizing, DA	PyTorch	DenseNet-169 + ASPP Layer	Standard	NA	NA	NA	F1-score=84.6 AUC=94.8 Acc=83
[30]	Different Datasets	CT-Scan	110 Axial CT-Scan Images From 60 Patients	Resizing, Grey Scaling (GL), DA	NA	Residual Attention U-Net	9 ResNeXt blocks+14 Layers	Sigmoid	Visualization	10	Acc=89 Pre=95 DSC=94
[31]	COVID-CS1 Dataset	CT-Scan	0144,1671CT-Scan Images of 400 COVID-19 Patients and1350 Uninfected Cases	DA, Segmentation using Encoder-Decoder Model	NA	Res2Net	Standard	Softmax	Visualization of Activation Mapping	NA	Avg Sen=95 Spe=93 Dice Score=78.3
[32]	Italian Society of Medical and Interventional Radiology	CT-Scan	473 CT Slices for COVID-19	Resizing, GL, Intensity Normalization	Keras	U-Net	50	Sigmoid	Visualization	NA	Dice Score=83.1 Sen=86.7 Spe=99.3
[33]	6 Different Datasets	X-ray	Different Number of Cases	Histogram, Segmentation using U-Net, Intensity Normalization	PyTorch	ResNet18	Standard	Softmax	t-SNE Clustering	NA	Acc=100 Sen=100 Spec=100 F1-score=100
[34]	COPD Dataset (Pretrain) COVID-19 Set	CT-Scan	5000 COPDGene, Subjects 470 COVID-19 Subjects	Standard Preprocessing	PyTorch	RTSU-Net	2 RU-Net	Sigmoid, Softmax	Different Methods	NA	IOU=92.2 ASSD=86.6

(Table 2 Contd.)...

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[35]	TCIA Dataset (Pretrain) COVID-19 Clinical Dataset	CT-Scan	60 3D CT-Scan Lung	DA, Fixed-Sized Sliding Window, Segmentation using U-Net	Tensor Flow	CNN	27	Softmax	0Multi-Window Voting1 Post-Processing Procedure 0 and1a Sequential Information Attention Module, CAM, 0 Categorical-Specific 1 Joint Saliency	5	Acc=96.2 Pre=97.3 Sen=94.5 Spe=95.3 AUC=97
[36]	Dataset I	X-ray	466 Normal, 860 Bacteria, 433 Viruses	Adaptive Histogram, CLAHE Method, MoEx, Use U-Net to Segment Lung Area (VGG19),DA	NA	Cascade-SEMENet	Modified Version	Sigmoid	Grad-CAM	NA	Acc=85.6 F1-Score=86
	Dataset II		210 COVID-19, 330 Others								Acc=97.1 F1-Score=97
[37]	Combination of Different Dataset	CT-Scan	449 COVID-19 Patients, 100 Normal, 98 Lung Cancer, 397 Other Pathology	Resizing, Intensity Normalization	Keras with Tensor-Flow Backend	Encoder and Two Decoders (2D U-NET Architecture) and MLP	24, 24, 15	Sigmoid	NA	NA	Acc=86 Sen=94 Spe=79 AUC=93 DSC=78.5
[38]	Clinical	CT-Scan	313 COVID-19, 229 Non-COVID-19	Normalizing, Resampling, DA, 3D Lung Mask Generation using 2D U-Net	PyTorch	DeCoVNet	20	Softmax	NA	NA	Acc=90.8
[39]	Clinical	CT-Scan	877 COVID-19, 991 Non-COVID-19	Visual Data Annotation and Quality, Normalization, 3D U-Net++ for Segmentation, DA	PyTorch	ResNet50	Standard Version	Softmax	NA	NA	Sen=97.4 Spe=92.2 AUC=99.1
[40]	Clinical	CT-Scan	1266 COVID-19 Patients, 4106 Patients with Lung Cancer (Auxiliary Training Set)	DenseNet121-FPN for Lung Segmentation, 3-Dimensional Bounding Box, Non-Lung Area Suppression Operation	Keras	COVID-19Net	4 Dense Blocks +9 Layers	Sigmoid	Combined Feature Vectors, Multivariate Cox Proportional Hazard Model, Visualizations	NA	Acc=81.24 AUC=0.90 Sen=78.93 Spe=89.93 F1-Score=86.92

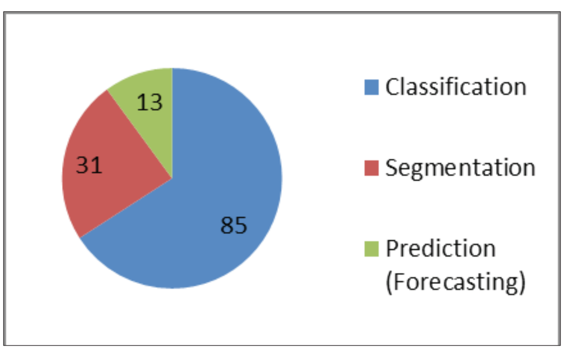

Fig. 1: Total Number of Investigations Conducted in the Field of Classification, Segmentation, and Prediction of COVID-19 Patients using DL Techniques

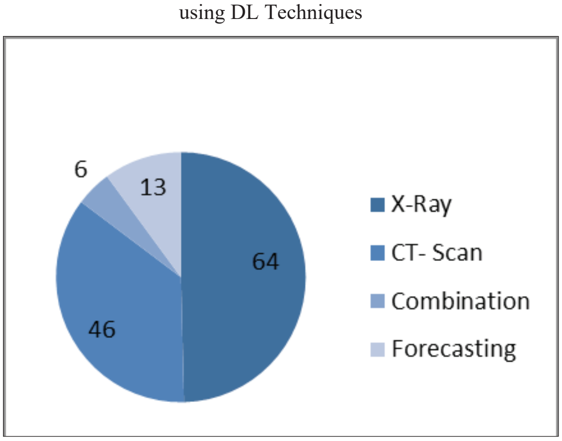

Fig. 2: Number of Datasets Used for COVID-19 Detection and Prediction Based on the Published Papers using DL Methods

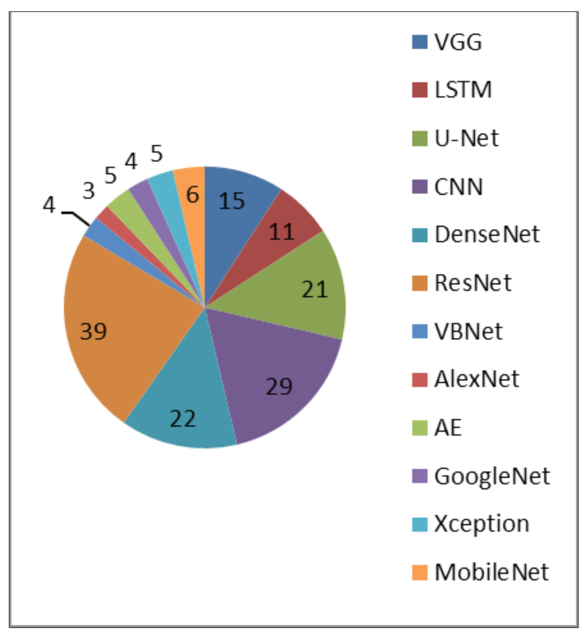

Fig. 3: Number of DL Architectures Used for COVID-19 Detection and Prediction Based on Published Papers

IV. Background

This background portion presents a recent review of the literature used for the diagnosis of the COVID-19.

Although very little literature is available in the COVID-19 trial, due to its new emergence, there are few technical updates in this field. In an effort, the authors in

[1] developed an AI engine based on experiment of DL to detect COVID-19 disease using high-resolution CT images. However, their proposed model relies solely on CT imaging.

In another study, authors of [8] compatible algorithms used smartphone sensors to detect the first effects of coronavirus COVID-19. The proposed framework consists of four distinct layers namely: input / learning sensor testing layers, sensory suspension layer, computer signal layer and disease prediction layer using an integrated machine learning method. Also, the machine learning model in the final stage can continue to be developed using the transfer learning method where the model works in the cloud.

The authors highlighted the mechanized prediction of COVID-19 using a pre-trained transfer model and Chest X-ray images [9]. For this purpose, they have used ResNet50, InceptionV3 and Inception-ResNetV2 pre-trained models to obtain high predictive accuracy for small X-ray databases. The new version of this paper is summarized as follows: 1) the proposed models have end-to-end structures without the removal of the feature and selection methods. 2) We show that ResNet50 is an efficient pre-training model among the other two previously trained models. 3) Chest X-ray images are an excellent tool for detecting COVID-19. 4) Pre-trained models have been shown to deliver the highest results on a small database (50 COVID-19 vs. 50 Normal).

Some authors in [10] have proposed a DL study model for the reflexive diagnosis of COVID-19. The future model has an end-to-end design without using any feature removal techniques, and further need X-ray chest images included to retrieve the diagnosis. This model was trained with 125 chest X-ray images, which were not standardized and were quickly detected. Diagnostic tests performed after 6 to 14 days of duration after detecting the infection found in the patient [11]. These important findings reflect the possibility of spreading of virus from diagnosed patients also. Therefore, more accurate diagnostic methods are needed. One of the most important problems in chest radiography analysis is the incompatibility to detect the initial stages of COVID-19, as they do not have sufficient sensitivity to GGO detection [12]. However, proposed framework based on DL that is well-trained can apply on those objectives that are not visible to the human eye, and can work to reverse this view.

The authors in [13] present a feature based on the deep learning study of machine learning and diagnostic methods for obtaining a computer-assisted diagnosis of COVID-19 pneumonia. Many ML algorithms are trained in chemically derived elements that are well-established at CNN to find the best combination of features and readers. Given the difficulty of high visibility of image data, in-depth feature releases should be considered as a critical step in building deeper CNN models. Test results obtained from the chest X-ray and CT dataset show that features derived from the design of DesnseNet121 and trained by the Bagging tree classifier produce more accurate predictions of 99.00% depending on the accuracy of the categories.

Of the [14] authors, they conducted a comprehensive study of the use of DL's COVID-19 lung differentiation techniques and lung automation are discussed, focusing on activities that used X-Ray and CT imaging. In addition, paper reviews were introduced on the prediction of coronavirus statistics in different parts of the world with DL strategies. Finally, the challenges facing the automatic detection of COVID-19 using DL strategies and guidelines for future research are discussed.

V. Conclusion

COVID-19 is a worldwide epidemic. Wise medical imaging has played an important role in combating COVID-19. The disease is accurately detected by the specialists using X-ray or CT images together with PCR results. The PCR results indicate the type of lung disease, such as pulmonary tuberculosis, instead of COVID-19. In this review paper, a comprehensive review of the accomplished studies of COVID-19 diagnosis was carried out using DL networks. The public databases available to diagnose and predict COVID- 19 are presented. The state-of-art DL techniques employed for the diagnosis, segmentation, and forecasting of the spread of COVID-19 are presented in Tables 2 and 3 respectively. I strongly feel that, with more public databases, better DL models can be developed by researchers to detect and predict the COVID19 accurately. Hence, this will help to develop the best performing model. The features extracted from the ML and DL models can be used to develop an accurate model.

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