A Comprehensive Analysis on COVID-19 Detection using AI Techniques and CT Images

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COVID-19 (Corona virus) is an infective disease induced by SARS-CoV-2 (novel coronavirus) which was initially materialized in December 2019 at Wuhan and public health emergency was declared on January 30 and March 11, 2020. The WHO declared it an epidemic. Coronavirus SARS-CoV-2 has its ecological origin in bat populations and through zoonotic sources, it is transmitted to humans. The Intermediate zoonotic sources have not been named so far. This COVID-19 has spread globally, giving rise to an existential health crisis across the world. Medical imaging for instance CT (computed tomography) and X-ray plays an indispensable part in the worldwide bear up against COVID-19. This review paper study and analyze AI techniques involved to find the trace of Coronavirus in people using chest CT.

Keywords: Covid-19, CT image, Segmentation, Pneumonia, CNN, U-Net, U-Net++, VB-Net, AI.

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1 Introduction

SARS-CoV-2 (COVID-19) has spread globally from which the world is facing global health crisis [1], [2]. CSSE disclosed that the total cases have reached 21.8 million (21,814,597) and fatalities stood at 772,782 [3] (Updated August 18, 2020). The Table 1 shown below some up total cases and deaths reported in various countries in order which is given by CSSE figure [3] and the same is represented in figure 1.

Table 1. List of cases and deaths in several states

S. No.	Countries	Deaths	Cases
1	US	170,491	5,437,969
2	Brazil	108,536	3,359,570
3	India	50,921	2,647,663
4	Russia	15,707	925,558
5	South Africa	11,982	589,886
6	Peru	26,281	535,946
7	Mexico	> 10,000	525,733
8	Colombia	15,097	468,332
9	Chile	10,513	387,502
10	Spain	28,646	359,082
11	Iran	19,804	345,450
12	UK	41,454	321,060
13	Saudi Arabia	>10,000	299,914
14	Argentina	>10,000	299,126
15	Pakistan	>10,000	289,215
16	Bangladesh	>10,000	279,144
17	France	30,434	256,533
18	Italy	35,400	254,235
19	Turkey	>10,000	250,542
20	Germany	>10,000	226,700
21	Iraq	>10,000	180,133
22	Philippines	>10,000	180,133
23	Indonesia	>10,000	141,370
24	Canada	>10,000	124,218
25	Qatar	>10,000	115,368
26	Kazakhstan	>10,000	103,033
27	Ecuador	>10,000	101,751
28	Bolivia	>10,000	100,344

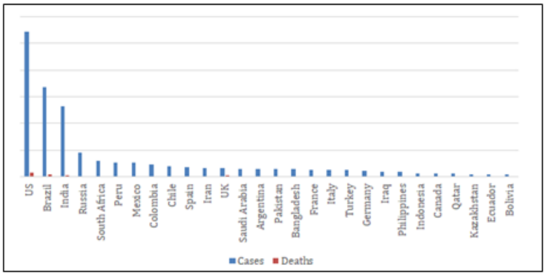

Fig. 1. Deaths and cases in several states

A) Imaging Modalities in Diagnosis of COVID-19

Presently there are two cases of diagnostic tests available to discover the active infection of COVID-19 in humans, 1) the RT-PCR detects the genetic material of the virus 2) the antigen detects distinct proteins on the airfoil of the virus. The other imaging techniques that are used in COVID-19 diagnosis are 1) Positron emission tomography (PET/CT), 2) Lung Ultrasound, 3) Magnetic resonance imagery (MRI) [23]. RT-PCR is most commonly used and it is as set as the gold standard [4].

1) Typical COVID-19 CT Characteristics

Chest CT (Computed tomography) images of COVID-19 suspects or patients can be assessed for the following features.

- **a.** GGO Presence
- **b.** Consolidates Presence
- **c.** Consolidation and laterality of GGO
- **d.** Lobes affected where either consolidative opacities or GGO are concede
- **e.** Level of interest of each lung lobe, in addition to the overall extent of lung involvement measured, as assessed by "total severity score"
- **f.** Nodules presence in lungs
- **g.** Caffeine or fluid for among the lungs pleural effusion
- **h.** Traces Thoracic lymphadenopathy
- **i.** Airway abnormalities
- **j.** Axial distribution of disease
- **k.** Traces of lung disease such as fibrosis or emphysema

2) Work flow of imaging-based diagnosis for COVID-19

The Imaging-based diagnosis work flow for the COVID-19, has three stages in general considering thoracic CT as an miniature i.e.,

- **a.** preparation for pre-scan
- **b.** Obtaining image and processing
- **c.** Diagnosis of disease and treatment.

In the first stage, each study is aided and guided by technician to take up a position on the two patient beds by following the given protocol. In the second stage, across a single breath-hold CT images are taken. From the peak to the lung base scan rates will be collected. Scan will be carried out from the upper thoracic inlet level to the cost phrenic angle of inferior level plus the enhanced parameters prepared by the radiologist's by considering the body shape of patient's. After obtaining the source, CT images will be sent through PACS (Picture Archiving and Communication Systems) by reconstructed the same and then for subsequent diagnosis and reading [5].

3) Segmentation Methods

Important step in COVID-19 image analytic thinking and processing is partitioning. It will depict the ROI (Regions of interest), for example: lesions, lung, lung lobes, and bronchus, in CT images for further quantification and assessment. Most desired COVID-19 segmentation networks are UNet++, U Net and VB-Net. At present segmentation works are very limited which is directly associated with COVID-19, never the less works is being carried out by considering the segmentation as required process in analyzing the COVID-19. Several machine learning methods like weakly supervised, semi-supervised, unsupervised and artificial techniques are employed with different functions. Table 2 summarizes illustrative works, including image segmentation in COVID-19 considers.

The reminder paper flow is formed as follows: Section 2 introduces the literature survey of several AI techniques is applied to detect the COVID-19 presence using CT images. Section 3 presents the comparative analysis of techniques that is discussed in the above section. Section 4 concludes the overall summary of the paper.

2 Literature Survey

CT scan is commonly done to give evidence for the radiologists. Nevertheless, an image, especially chest CT has many slices. To diagnose this image slices an extended juncture is required. COVID-19 is an epidemic disease which as identical symptoms with desperate form of pneumonia which require the concerned specialist to have numerous experience to achieve high diagnostic performance. Therefore, various diagnosis techniques aided by AI using medical images is much wanted. Here we study various works which used CT as a modality.

Wang et al. [18] use 1,065 pathogen-confirmed CT images 42 cases reported as COVID-19 including previously diagnosed typical 43 viral pneumonia. Inception transfer-learning model is modified to 44 to establish algorithm, subsequently by external and internal validation. 89.5% accuracy is achieved for internal 45 validations in total with 0.88 specificity and 0.87 sensitivity with 46 validations. Accuracy of 79.3% with 47 specificity of 0.83 and 0.67 sensitivity is achieved considering the external testing data. Out of 54 COVID-19 images, first 2 nucleic acid test were negative of 48, 46, 49 were COVID-19 positive as predicted by CNN algorithm, with 82.9% accuracy.

Jin et al. [13] use 1136 cases of chest CT images that are 413 COVID-19 negatives and 723 COVID-19 positives in the field. ResNet50 based classification and UNet++ based segmentation is their proposed model. Segmentation model is used to spotlight lesion region which is input to classification model. They have obtained 97.4% and 92.2% sensitivity and specificity respectively by conducting experiment trough UNet++ and ResNet50.

Xu et al. [20] used 219 patients chest CT images with COVID-19 out of which 175 were healthy and 224 patients were with Influenza-A. To segment the candidate infection region V-net is first applied which is based on deep learning model. A spot of infected region together with characteristic of relative infection was transmitted to Resnet-18 network; one of these three groups was the end product. The proposed model achieves overall 86.7% accuracy.

Zheng et al. [15] CT images of 540 patients were used where in with COVID-19 were 313 and without COVID-19 were 299 to test and train the data. They have proposed U-Net+3D which are a CNN based model, used for lung segmentation and the input for 3D CNN to predict the probability of COVID-19 was the same segmentation solution. An experimental result shows accuracy of 0.959, sensitivity of 90.7%, specificity 91.1%.

Shi et al. [21] used 2685 patient's chest CT images out of which 1027 patients were suffering from common pneumonia and 1658 patients were COVID-19 affected. Left or right lung image was segmented, 18 pulmonary segments and to segment 5 lung lobes, a VB-Net is used in the preprocessing stage. Results show 90.7% sensibility, 83.3% specificity and 87.9% accuracy.

Table 2. COVID-19 Image Segmentation Methods

Authors	Modality	Target ROI	Method	Application
Shan *et al.* [6]	CT	Lung , Lung lobes, Lung segments, Lesion	VB-Net, Human-in-the-loop	Quantification
Tang *et al.* [7]	CT	Lung, Lesion, Trachea, Bronchus,	Commercial Software	Quantification
Chen *et al.* [8]	CT	Lesion	UNet++	Diagnosis
Gozes *et al.* [9]	CT	Lung, Lesion	U-Net/ Commercial Software	Diagnosis
Shen *et al.* [10]	CT	Lesion	Threshold-based region growing	Quantification
Qi *et al.* [11]	CT	Lung lobes, Lesion	U-Net	Quantification
Cao *et al.* [12]	CT	Lung Lesion	U-Net	Quantification
Jin *et al.* [13]	CT	Lung Lesion	UNet++ Joint segmentation and classification	Diagnosis
Huang *et al.* [14]	CT	Lung Lung lobes lesion	U-Net	Quantification
Zheng *et al.* [15]	CT	Lung	U-Net Weakly-supervised method by pseudo labels	Diagnosis
Li *et al.* [16]	CT	Lesion	U-Net	Diagnosis

Ying et al. [19] used 88 COVID-19 patient's chest CT images; bacterial pneumonia with 101 and people who were healthy was 86. Using ResNet50 they have proposed CT diagnosis system called Deep Pneumonia based on deep learning. Input for this Deep Pneumonia is the slices of complete lungs which are derived from CT images. Model achieves 86.0% accuracy pneumonia classification and 94.0% accuracy for pneumonia diagnosis.

Tang et al. [22] used 176 patient's chest CT images which include COVID-19 confirmed cases. RF-based model for COVID-19 severity assessment was proposed which is non-life threatening or dangerous.

To carve up the lung into anatomical sub-areas they have adopted VB-Net which is a deep learning model. This model gives the count of infection proportions and volumes of each anatomical sub-region and it is also used as quantitative feature to develop RF model. Experimental result shows 93.3% true positive, 74.5% true negative and 87.5% accuracy.

Li et al. [16] used bulk CT dataset that has 4356 CT images from 3322 patients which includes 1735 community-acquired pneumonia, 1296 COVID-19 and 1325 non-pneumonia. To distinguish between COVID-19 with non-pneumonia and CAP (Community-acquired Pneumonia) a ResNet50 model is used on shared weights with max-pooling and on 2D slices. Experimental results shows 90% sensitivity, 96% specificity and 0.96 AUC in recognizing COVID-19.

Chen et al. [8] used CT images of 51 COVID-19 patients CT images and 55 patients with other disease to train UNet++ deployed segmentation model. This accounts the COVID-19 related lesions segmentation. Segmentation lesions are considered as base to set the final label. Additionally 11 non-pneumonia and 16 viral pneumonia patients data set was included. Proposed model identified all pneumonia patients and nine non-pneumonia patients. After experiment they have achieved 100% sensitivity and 93.6% specificity and have achieved 95.2% accuracy using the proposed model. Proposed model shortens the reading time of radiologists.

Jin et al. [17] used CT images of 1385 negative cases and 496 COVID-19 Positive cases. To identify slices of positive COVID-19 cases and segment the lung 2D CNN model is proposed. They have achieved 94.1% sensitivity and 95.5% specificity with AUC 0.979 after experiment.

3 Comparative Analysis

Various AI techniques and methods applied to detect the COVID-19 by considering CT as modality is presented in Table 3. The subjected cases and consequences are summarized in the same table. Accuracy is represented in percentage and the sensitivity and specificity results are also specified. The same is represented in figure 2.

Table 3. AI-assisted Diagnosis of COVID-19 using CT images

Authors	Modality	Subjects	Task	Method	Result
Wang *et al.* [18]	CT	44 COVID-19, 55 Vir. Pneu.	Classification: COVID-19/ Vir. Pneu.	CNN	82.9% (Acc.)
Jin *et al.* [13]	CT	723 COVID-19, 413 Others	Classification: COVID-19/ Others	UNet++ CNN	97.4% (Sens.) 92.2% (Spec.)
Xu *et al.* [20]	CT	219 COVID-19, 224 Influ.-A , 175 Normal	Classification: COVID-19/ Influ.-A/ Normal	CNN	86.7% (Acc.)
Zheng *et al.* [15]	CT	313 COVID-19, 229 Others	Classification: COVID-19/ Others	U-Net CNN	90.7% (Sens.) 91.1% (Spec.) 0.959 (AUC)
Shi *et al.* [21]	CT	1658 COVID-19, 1027 CAP	Classification: COVID-19/CAP	RF	87.9% (Acc.) 90.7% (Sens.) 83.3% (Spec.)
Ying *et al.* [19]	CT	88 COVID-19, 100 Bac. Pneu., 86 Normal	Classification: COVID-19/ Bac. Pneu./ Normal	ResNet-50	86.0% (Acc.)
Tang *et al.* [22]	CT	176 COVID-19	Severity assessment	RF	87.5% (Acc.) 93.3% (TPR) 74.5% (TNR)
Li *et al.* [16]	CT	468 COVID-19, 1551 CAP, 1445 Non-pneu.	Classification: COVID-19/ CAP/ Non-pneu.	ResNet-50	90.0% (Sens.) 96.0% (Spec.)
Chen *et al.* [8]	CT	51 COVID-19, 55 Others	Classification: COVID-19/ Others	UNet++	95.2% (Acc.) 100% (Sens.) 93.6% (Spec.)
Jin *et al.* [17]	CT	496 COVID-19, 1385 Others	Classification: COVID-19/ Others	CNN	94.1% (Sens.) 95.5% (Spec.)

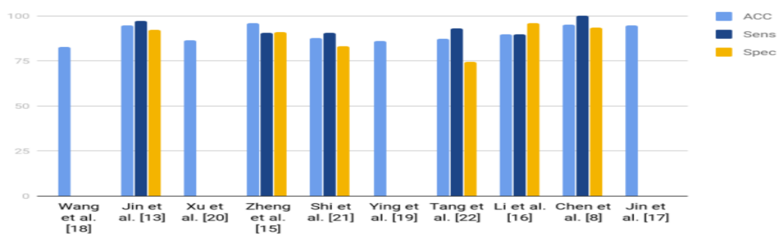

Fig. 2. AI-assisted Diagnosis using CT images for COVID-19

4 Conclusion

The Corona virus (COVID-19) may be an epidemic disease which has spread across the world. An intuitive restorative image plays a vital part in encountering with COVID-19. This paper summarizes various techniques of AI with CT images that gives secure, precise and adequate imaging line-up for solicitations of COVID-19. Computed tomography stages, clinical determination also spearheading inquiries are checked in detail, that embraces the whole line of Artificial Intelligence empowered CT image COVID-19 solicitations. CT is utilized to illustrate the viability of Artificial Intelligence empowered restorative image for COVID-19. Notice that imaging gives partial information about patients with COVID-19. It's imperative to combine clinical signs with imaging information and research facility assessments comes about to assist the screening, location and determination of COVID-19. AI illustrates the capability in melding data from this multi-source information for precise performance, productive analysis and diagnosis.

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