Federated Deep Learning Approaches for Detecting COVID-19: A Study

Renjini P. S.,
Department of Computer Science and Engineering
Rajagiri School of Engineering and Technology, Ernakulum, Kerala, India

Jyotsna A.
Department of Computer Science and Engineering
Rajagiri School of Engineering and Technology, Ernakulum, Kerala, India

Abstract- The beginning of 2020 has seen the emergence of corona virus outbreak resulting from a novel virus known as SARS-CoV-2. This sudden explosion and uncontrolled international unfold of COVID-19 shows the limitations of current healthcare systems in timely handling public health emergencies. However, the recent studies have proved that artificial intelligence and machine learning can be used to fight COVID-19. Deep learning techniques are powerful tool for picture analysis.There is lots of research works going on for COVID-19 case detection with the aid of deep learning with X-ray photos. Such techniques needs massive datasets for training and all such statistics need to be centralized as a way to be processed.Due to scientific information privacy guidelines, it's far often no longer possible to acquire and percentage patient information in a centralized records server. This paper aims to study federated deep learning frameworks for COVID-19 detection which allows detecting COVID-19 using deep learning approaches with data privacy ensured.

Keywords – Deep learning (DL) , Federated learning(FL), Artificial neural network (ANN),Internet-of-Things(IoT)

I. INTRODUCTION

With the outbreak of an unknown disease in late 2019 in China, some people became infected with the disease.The disease was completely unknown at first, but specialists diagnosed its symptoms as similar to those of a virus infection and flu. Later it was found by the use laboratory examinations and analysis of positive sputum by real-time polymerase chain reaction (PCR) test, and this infection is eventually named "COVID-19" caused by corona virus ,upon the recommendation of the World Health Organization (WHO). Over a short period, the COVID-19 epidemic crossed geographical boundaries with a devastating effect on the health, economy, and welfare of the global population.

The early detection of COVID-19 is essential not only for patient care but also for public health by ensuring the patients' isolation and controlling the pandemic. Due to the novelty of the disease, ways to fight it were not known in the early days, but researchers considered screening and rapid diagnosis of infected patients and their separation from the community of healthy people as an important measure. The clinical features of COVID-19 include respiratory symptoms, fever, cough, dyspnea, and pneumonia. However, these symptoms do not always indicate COVID-19 and are observed in many cases of pneumonia, leading to diagnostic problems for physicians. The massive and sudden spread of the corona virus (COVID-19) has overwhelmed the world for more than a year since the initial cases were reported. Corona virus triggers an acute respiratory infection in the lungs causing a large number of deaths. Due to the highly contagious nature, COVID-19 detection remains among high-priority tasks. Currently, a nucleic acid test by sampling throat and nasopharyngeal swabs is the most feasible way for the diagnosis. However, sampling error and low viral load affect the diagnosis results in terms of accuracy. In contrast, the antigen tests are comparatively faster, but, have poor sensitivity. Besides the pathological tests, radiological examinations in the form of chest Computed Tomography (CT)and X-ray imaging also contribute in recognizing the infection in patients.

To improve the detection accuracy, a significant series of deep learning (DL) models are proposed which detect different types of infection by analyzing the CT and X-ray images. Based on a small set of available infected samples deep learning models are trained and improved accordingly. However, sensitivity and accuracy are still compromised due to the lack of training data. Traditional federated learning is the natural solution for such problem. Federated learning collects locally trained models from the different sources and collaboratively train a global model over the decentralized

network.
Deep learning has shown a dramatic increase in the medical applications in general and specifically in medical image based diagnosis. Artificial neural networks (ANNs) outperformed other conventional models and methods of image analysis. Federated Learning(FL) is an machine Learning architecture to address the data privacy issue by collaborative training approaches that do not require a single pool of centralized data. To build a machine learning model based on distributed datasets without sharing raw data while preserving data privacy. Each client has a data set and his local machine learning model. There is usually a centralized global server in the federated environment that has a centralized machine learning model, which aggregates the distributed client's model parameters. Each client trains the local machine learning model locally on a data set and shares the model parameters to the global model. The global model makes iteration of rounds to collect the distributed clients model updates without sharing raw data.

II. ROLE OF FL AND DL IN COVID - 19 DETECTION

The clinical symptoms of COVID-19 are mostly a dry cough, fever, chills, and systemic pain although some patients have abdominal manifestations.Current COVID-19 detection and classification DL approaches are mainly based on, including but not limited to, pre-scan, laboratory testing and medical image (CXR and computed tomography [CT]) analysis. Pre-scanning approaches analyse coughing and breathing data, which could be a first step in the diagnosis and detection of COVID-19. However, these approaches are not robust and cannot replace clinical testing.

The timely infection detection by additional screening and combining the antibody testing with quantitative-polymerase chain reaction (qPCR)can significantly improve detection sensitivity and accuracy, however, incorrect sample collection in qPCR or false-negative diagnosis can result in grave consequences by allowing diseased patients to spread the virus. Medical imaging such as CXR and CT scan analysis is one of the most auspicious research fields which facilitates the diagnosis of viral infections like COVID-19. In comparison, CT images are more powerful in detecting viral infections however less accessible and a costly test to the public, although CXR images perform the same task with greater accessibility and relatively at a lower cost.However, it should be noted that these approaches are unable to efficiently address data privacy concerns, the in-feasibility of model generalization due to small data sets, centralized processing, a lack of set criteria for the selection of the most suitable algorithm for a precise problem, expensive model training, and communications and implementations requirement. Here FL is useful in addressing these issues to some extent.

FL is an ML architecture to address the data privacy issue by collaborative training approaches that do not require a single pool of centralized data. A basic federated learning model is shown in figure 1.

2.1. A basic FL model implementation detail in healthcare setting in listed below –

Step 1: Central server initializes the training model from its local data.

Step 2: Central server synchronizes (or transmits) the model to participating hospitals/clients.

Step 3: Upon receiving the model from the server, each hospital trains the model locally with their own data samples.

Step 4: Each hospital returns the locally trained incremental model updates to the central server. Then, the central server aggregates the model results and generates a global model without knowing the individual data samples of the hospitals.

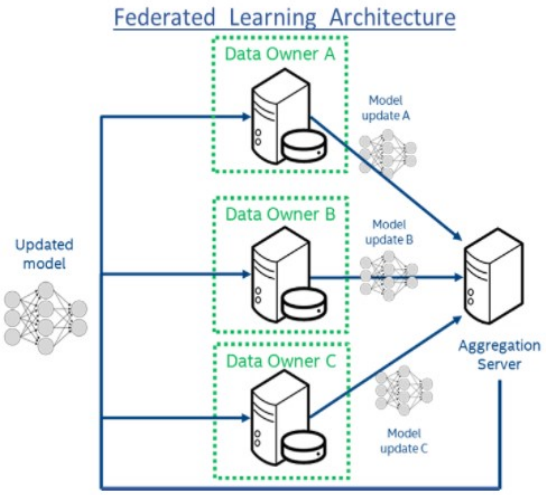

Figure 1: Basic FL model architecture

Deep Learning techniques have efficiency in tackling a huge amount of curated data to feature millions of parameters to gain precise, unbiased, secure, and generalizable, medical grade outputs.However, high quality full spectrum curated medical data are often hard to obtain .The collection of such data is challenging and may have substantial business value as it requires significant time, cost, and energy, thus making it improbable to access publicly. By combining deep learning and federated learning , best detection accuracy can be obtained while preserving data privacy.

III. RELATED WORK

In [1] the author found that main problem for the detection of COVID-19 from the symptoms is because of the uncertainty of the data. According to the results of the COVID-19 infected patients, the majority got hospitalized with high fever, cough with sputum, and shortness of breath. Patients with hypertension, cardiovascular disease, and high pulse rate are quick to progress to the next stage once they get infected with COVID-19. Once the virus progresses to acute respiratory disease syndrome (ARDS), there could be respiratory failure, septic shock, and multiple organ failure. Based on the symptoms, infected status is possible to find out. The outcome, i.e., infected status, has been classified into three classes, which are not infected, mildly infected, and severely infected. The classes have been mapped to the numerical values as: Severely Infected ¼ 1; Mildly Infected ¼ 2; Not Infected ¼ 3.
In [2] a deep learning model computation consists of two stages, namely training and inference is used. Training is iterative and stochastic computation used for generating a model based on training data. Several arguments need to be initialized before training, including learning rate, epoch number, and batch size, where different configurations tend to result in models with different accuracies. Inference is a prediction process with the trained deep learning model. Some popular deep learning architectures are available, e.g., CNN and recurrent neural networks (RNN).

In [3] a hybrid learning paradigm that is able to produce more accurate and robust prediction results than a single model by combining multiple machine learning models intelligently is used . A multi-layer neural network that can progressively extract higher level features from raw data such as images and produce prediction outputs based on those features. EDL-COVID is based on COVIDNet, which is state-of the-art open-sourced deep CNN for COVID-19 case detection from CXR images. This paper used COVIDNet network architecture as well as its datasets of COVIDx.first training is done on multiple snapshot deep learning models with a cosine annealing learning rate schedule, for which the learning rate fluctuates significantly in that it starts high and drops to a minimum value close to zero rapidly before going up to the maximum value again. Next, the ensemble deep learning model of EDL-COVID is developed by combining these models with a proposed model ensembling approach called weighted averaging ensembling (WAE), which is based on two observations that 1) there are different sensitivities for different classes types of an individual deep learning model, and 2) different deep learning models have different sensitivities for each class type. WAE is based on the assumption that for a class type, a model with a higher

sensitivity should contribute more to the final ensembling result by estimating its weight proportional to its sensitivity.

In [4] a deep convolutional neural network (CNN) and Fl is used to deal with the feature extraction and the classification of X-ray images to detect the COVID-19 disease. This model takes as input an X-ray image and outputs the probability of COVID19 infection. The learning phase of this CNN model consists of several communication rounds where the central server interacts synchronously with the clients. In [5] Blockchain and artificial Intelligence(AI) are used to provide viable solutions to cope with the coronavirus epidemic from various aspects. In fact, block chain has been applied to other infectious epidemics, such as Ebola where blockchain was employed to conduct real-time Ebola contact tracing, transmission pattern surveillance and vaccine delivery. This project also reveals that the cryptographic feature of blockchain can help prevent unsecure data sharing between patients and health entities such as healthcare providers. In the coronavirus outbreak fighting, blockchain can actively simplify the process of fast-tracking drug trials, and recording and tracking all fundraising activities and donations, in an immutable fashion, which can support the management of outbreaks and treatment. In research paper [6] the author examined the performance of different pre-trained models on CT testing and identified that larger, out-of-field datasets boost the testing power of the models. This suggests that a priori knowledge of the models from out-of-field training is also applicable to CT images. The proposed transfer learning approach proves to be more successful than the current approaches.

In [7] a hybrid 3D deep learning model (H3DNN) is used. H3DNN makes use of I3D and 3D Resnet 50 to screen out COVID-19 patients. The model automatically and effectively detects the COVID-19 patients at a low cost in terms of annotations of CT images by ensembling the Inflated inception (I3D) and 3D ResNet 50 to build a common architecture for capturing the Spatio-temporal dimension including the inception block.

In [8] a two-stage Convolutional Neural Network (CNN) based classification framework for detecting COVID-19 and Community Acquired Pneumonia (CAP) using the chest Computed Tomography (CT) scan images is used. COVID-19 and CAP detection system using deep learning, termed as COVID+CAP-CNN, consists of two stages. In the first stage, unlabelled CT scans in the SPGC dataset are labeled using a pre-trained CNN-based algorithm. In the second stage, labeled slices are pooled into individual-level estimates of COVID-19, CAP infected patients, and normal individuals using the Efficient Net architecture.

In [9] a deep learning based method that uses chest X-ray images from normal, COVID-19 and viral pneumonia patients is proposed to enable automatic detection of COVID-19 patients. In addition, Canny, Roberts, Sobel edge detection methods were applied to the images to determine the lesioned area or the perimeter of the area where they are restricted to examine the effect of deep learning on the classification performance.

In [10] , an IoT-based framework for the early assessment of Covid-19 is used. The medical sensors/devices collected chest X-Ray samples that are directly fed into a deep learning architecture for the detection of Covid-19. Regional-based convolutional neural networks is capable of assisting medical experts or radiologists, relieve the working pressure, and might help in the control of pandemic.

A comparative analysis of papers mentioned in the related work is shown in table 1.

Table -1 Experiment Result

S.No.	Approach Used	Advantages	Limitations
[1]	SVM	Easy to find the result	No proper data set available

[2]	**Deep learning(CNN &RNN)**	**Computation consist of two stages, it improve the efficiency**	**Initialization is difficult**
[3]	**Hybrid learning**	**More accurate and robust prediction**	**Difficulty to design the model**
[4]	**Federated learning**	**Solve the data privacy issue**	**Communication overhead**
[5]	**Block chain based AI**	**Prevent insecure data sharing**	**Difficulty to implement**
[6]	**Transfer learning approach -AI**	**More successful than current approaches**	**No proper data set is available**
[7]	**Hybrid 3D deep learning model**	**Low cost & effectively detect the covid-19**	**Difficulty to design since it is a hybrid one**
[8]	**Two –stage CNN**	**Efficient diagnosis**	**Needs more importance to each CNN structure**
[9]	**Deep learning**	**Efficient and accurate**	**Only in used in less amount of data set**
[10]	**IoT based framework:Regional-based convolutional neural networks**	**More accurate than previous.**	**Computational cost is high**

3.1. Data set

Mostly up-to-date COVID-19 data are provided by government organizations. Open source COVID-19 data sets are in raw text format and are often unstructured. Raw data in the form of comma separated value (CSV) files permit a quick and easy data download yet require substantial data pre-processing is required to prepare it for further analysis. Several datasets have been built and are open for researchers, doctors, and data scientists for COVID-19-related research. Currently, although the COVIDx-CT data set is evidently larger than many other CT datasets used in the literature on COVID-19 testing, a potential limitation of using COVIDx-CT for deep neural network learning lies in the limited patient demographic diversity.

IV.CONCLUSION

Detect the Covid- 19 instances primarily based on signs on the early stage can be done effectively by the usage of machine learning approaches. The availability of right scientific photo data set is a the risk in deep learning techniques for COVID detection to locate sickness more appropriately . However,via federated learning privacy preserved manner of analysis can be done in a decentralized manner. And there is a centralized worldwide server in a federated surroundings which aggregates the dispensed consumer's version parameters. Each consumer trains the neighborhood machine mastering model domestically on a data set and shares the model parameters to the worldwide model. The worldwide version makes new release of rounds to acquire the disbursed clients version updates without sharing uncooked facts. A framework that may utilize up-to-date information to improve the

recognition of computed tomography (CT) images and proportion the records among hospitals at the same time while maintaining data privacy.

REFERENCES

[1] Muhammad Nazrul Islam , Toki Tahmid Inan , Suzzana Rafi , Syeda Sabrina Akter, Iqbal H. Sarker ,and A. K. M. Najmul Islam "A Systematic Review on the Use of AI and ML for Fighting the COVID-19 Pandemic" IEEE TRANSACTIONS ON ARTIFICIAL INTELLIGENCE, VOL. 1, NO. 3, DECEMBER 2020.

[2] Aijaz Ahmad Reshi ,1 Furqan Rustam ,2 Arif Mehmood ,3 Abdulaziz Alhossan,4,5 Ziyad Alrabiah,4 Ajaz Ahmad ,4 Hessa Alsuwailem,4 and Gyu Sang Choi 6 "An Efficient CNN Model for COVID-19 Disease Detection Based on X-Ray Image Classification" Volume 2021 |Article ID 6621607 | https://doi.org/10.1155/2021/6621607.

[3] Shanjiang Tang , Chunjiang Wang , Jiangtian Nie , Neeraj Kumar , Senior Member, IEEE, Yang Zhang , Member, IEEE, Zehui Xiong , Member, IEEE, and Ahmed Barnawi "EDL-COVID: Ensemble Deep Learning for COVID-19 Case Detection From Chest X-Ray Images" IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, VOL. 17, NO. 9, SEPTEMBER 2021.

[4] Ines Feki a , Sourour Ammar a,b , Yousri Kessentini a,b,Khan Muhammad "Federated learning for COVID-19 screening from Chest X-ray images" Applied Soft Computing 106 (2021).

[5] Dinh C. Nguyen; Ming Ding; Pubudu N. Pathirana; Aruna Seneviratne "Blockchain and AI-Based Solutions to Combat Coronavirus (COVID-19)-Like Epidemics: A Survey" Digital Object Identifier 10.1109/ACCESS.2021.3093633 VOLUME 9, 2021.

[6] Zhao, W., Jiang, W. &Qiu, X. Deep learning for COVID-19 detection based on CT images. *Sci Rep* **11,** 14353 (2021).https://doi.org/10.1038/s41598-021-93832-2.

[7] A. A. Khan, S. Shafiq, R. Kumar, J. Kumar and A. U. Haq, "H3DNN: 3D Deep Learning Based Detection of COVID-19 Virus using Lungs Computed Tomography," *2020 17th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAMTIP)*, 2020, pp. 183-186, doi: 10.1109/ICCWAMTIP51612.2020.9317357.

[8] S. Chaudhary, S. Sadbhawna, V. Jakhetiya, B. N. Subudhi, U. Baid and S. C. Guntuku, "Detecting Covid-19 and Community Acquired Pneumonia Using Chest CT Scan Images With Deep Learning," *ICASSP 2021 - 2021 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, 2021, pp. 8583-8587, doi: 10.1109/ICASSP39728.2021.9414007.

[9] D. Narın and T. Ö. Onur, "Investigation of the Effect of Edge Detection Algorithms in the Detection of Covid-19 Patients with Convolutional Neural Network-Based Features on Chest X-Ray Images," 2021 29th Signal Processing and Communications Applications Conference (SIU), 2021, pp. 1-4, doi: 10.1109/SIU53274.2021.9477882.

[10] I. Ahmed, A. Ahmad and G. Jeon, "An IoT-Based Deep Learning Framework for Early Assessment of Covid-19," in IEEE Internet of Things Journal, vol. 8, no. 21, pp. 15855-15862, 1 Nov.1, 2021, doi: 10.1109/JIOT.2020.3034074.