A Study and Novel AI/ML-Based Framework to Detect COVID-19 Virus Using Smartphone Embedded Sensors

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Abstract SARS-CoV-2 also known as COVID-19 is a novel corona virus which originated from China. Corona virus disease COVID-19 is the official name given by WHO is caused by SARS (Severe Acute Respiratory Syndrome) which have very mild symptoms in the beginning but slowly progress to failure of multiple organs followed by death. The emergency committee of WHO declared COVID-19 as a pandemic. The disease is spread from person-to-person and the spread is very fast making serious impacts on the lives of the people. CT scan and PCR (Polymerase Chain Reaction) are the tests for the diagnosis of COVID-19 virus in the human body. The symptoms of this disease are very common which include fever, breath shortness, dry cough and pain in the muscles. The solutions which are available currently have less accuracy, take longer time and are costly. In this paper, a framework is proposed based on smart phones and artificial intelligence. The benefits are increased productivity, reliability and availability of advanced infrastructure. There are various sensors embedded in the smart phones such as proximity sensor, light sensor, accelerometer, gyroscope and fingerprint sensors which have very fast processors and memory space making it easy to read the sensors and scan the CT images, the signal measurements in the sensors of the smart phones are read which scan the CT images for reliable diagnosis of the disease. The proposed framework is based on artificial intelligence, cloud network and machine learning.

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1 Introduction

An infectious and communicable disease named COVID-19 is a novel corona virus which originated from China. The virus is known as severe acute respiratory syndrome corona virus 2 abbreviated as SARS-CoV-2 and generally known as corona virus disease COVID-19. Its epicenter is in the Wuhan city of China. Many respiratory diseases are caused from this virus as confirmed by the World health Organization in December 2019. The symptoms include high fever, dry cough, sore throat and difficulty in breathing as this virus directly attacks lungs. This virus has now become pandemic and has already affected many parts of the world. On 11th March World Health organization (WHO) declared COVID-19 as a pandemic in their emergency committee. The disease is spread from person-to-person and the spread is very fast making serious impacts on the lives of the people. The old-aged humans are most vulnerable to COVID-19 as they have comparatively less immunity than the younger population [1]. The recovery chances therefore becomes somewhat less in the elderly population of the world. Many species of animals are also affected by COVID-19, but in humans it has spread to a larger extent making it as an emergency situation in the health sector. Firstly, the disease spread from animal-to-person in Wuhan city of China which is the epicenter of this disease [2]. The people of Wuhan ate sea food which was infected from COVID-19, thus spreading it from animal-to-person. Now, the virus is continuously spreading from person-to-person in a fast manner. Therefore, the persons having no contact with live animals also became the victim of COVID-19 due to person-to-person spread [3]. Corona virus disease (COVID-19 is the official name given by WHO) is caused by SARS (Severe Acute Respiratory Syndrome) which have very mild symptoms in the beginning but slowly progress to failure of multiple organs followed by death. The symptoms of this disease are very common which include fever, breath shortness, dry cough and pain in the muscles [4]. But there are many people out there in the population which do not show any kind of symptoms and thus the fatality rate is overestimated. All these symptoms slowly progress to other health problems [5]. The person-to-person spread of the virus is caused through the respiratory droplets when the person coughs or sneezes. The patients showing these symptoms need to treat urgently so that there is low chances of the community spread. The life of the virus on the contaminated surfaces is about 72 h. The symptoms start to reveal within average 5 day. CT scan and PCR (Polymerase Chain Reaction) are the tests for the diagnosis of COVID-19 virus in the human body [6]. The physical distance needs to be maintained to prevent the infection. The main organ affected by the COVID-19 virus is the lungs as the host cells accessed by the virus through zyme ACE2 are found abundantly in the lung cells. The gastrointestinal organs are also affected by this virus. People having MERS (Middle East Respiratory Syndrome) and SARS are mostly affected by this virus. NAT (Nucleic Acid Test) is also one of the

techniques to diagnose COVID-19 disease. The sequence of nucleic acid that may be present in the form of a virus causing infections in the blood. The most effective way to diagnose COVID-19 is CT scan as it detects the serious inflammation in the lungs despite other detection kits and techniques [7]. the medical system gets overloaded due to multiple CT scans as the number of patients and the suspected cases are increasing exponentially everyday which also causes frustration in the people. The other patients get cross infected due to all these problems and therefore the risk factor increases. The physicians and medical systems are thus overloaded due to increasing number of patients for the CT scan which is the main functional test for COVID-19 disease. The radiologists and the medical staff is far less than the patients [8]. Due to this, the detection of the disease is late causing serious health problems in the patients. The suspected persons are advised to go into the quarantine so that they do not contact other people and therefore cross spreading could be prevented to some extent. In Italy, only the serious cases are being treated due to shortage of ventilators and hospital beds and that too when Italy has the best medical health care properties in the world [9]. Since, the pandemic COVID-19 is showcasing the nightmares, the expectations from scientists and academicians from all over the world is increasing for their efficient and intelligent response for detection methods. Many smart and intelligent techniques for CT scan are being revealed and studied by the scientists taking in account the accuracy and speed with which the detection is being done. The most perfect diagnosis for COVID-19 is not yet discovered as both CT scan PCR test are individually not enough to detect the virus accurately in the lungs. The perfect lies in the combination of numerous methods of diagnosis. The medical kits for the diagnosis of the virus are quite costly and requires installation. The research for the quick detection kit is continuous all over the world by several scientists and the companies. After the disease has been declared pandemic by the WHO there is an urgent need to treat the symptomatic patients who show the probable symptoms of COVID-19 disease just to lessen the community spread through these careers. Since asymptotic patients cannot be treated and their numbers have been increasing, so the treatment of the disease play a vital role. The old drugs are being repositioned for the antiviral treatment of COVID-19. This is because there are certain factors to be taken care of such as the side effects if mixing drugs and the drug interactions since the proper vaccine is still under testing. An anti malarial drug called chloroquine has a very significant inhibitor effect on SARS-CoV-2 virus. The outcome of the drug clinically has given an effective result and clearance of virus through this drug has also been observed in many patients in China. The patients showing very mild symptoms such as cough and mild cold could be treated with 500 mg dose of chloroquine twice a day for about 10 days. This drug was not recommended for the patients showing symptoms of pneumonia [10].

The computational capabilities of the smart phones which are used in modern times is very powerful. They contain embedded sensors which enhance the capabilities of the smart phone. The information regarding daily activities can be easily sensed using smart phones. They even have the capability to capture the visual data with the help of several sensors embedded on the smart phones. The data from the suspected COVID-19 patients can be easily captured, collected and stored in the

smart phones. The CT images of the suspected patients could be easily scanned in the smart phones for the purpose of further research and analysis. The comparative analysis of the CT scan images fed in the smart phones can also be done leading to better detection of the virus. In this way the inflammation and the infection in the lungs can be monitored and analyzed with the help of CT scan images fed into the smart phones of the suspected COVID-19 patients [11]. The diagnosis of the corona virus disease officially called COVID-19 with the help of smart phone sensors and artificial intelligence (AI) is demonstrated in this paper. The framework presented in the paper provides a solution of low cost for dedicated smart phones used by the radiologists for the detection purpose. The people themselves can regularly monitor the infection in their lungs through the progressive CT scan images stored in their smart phones leading to early diagnosis of the disease. There are various sensors embedded in the smart phones such as proximity sensor, light sensor, accelerometer, gyroscope and fingerprint sensors which have very fast processors and memory space making it easy to read the sensors and scan the CT images, the signal measurements in the sensors of the smart phones are read which scan the CT images for reliable diagnosis of the disease. In this way the virus of the COVID-19 would be detected in a very short time as compared to the time taken by the radiologists to detect the virus. The development of the disease COVID-19 can be easily tracked and evaluated for treatment using this framework.

2 Smart Phones to Detect COVID-19

The pandemics or the infectious diseases which spread very quickly should be identified rapidly so that there is a proper and effective treatment to such diseases. But this process is very lengthy and complicated and large professional labs are needed to carry out the diagnosis of such pandemics. A diagnosis is received in hours and even days. More is the diagnosis time; more will be the delay in the treatment of patients since large time would spend in determining the virus. Therefore, a diagnostic system is being tested using the smart phone technology by various researchers all over the world. Smart phones integrate the cloud network with the chip device present in them [12]. This can help in detection of the disease in the initial stage even in the remote areas. The applications in the smart phones helps in the process of diagnosing and testing of the patients in a progressive manner. The sample of the patient is extracted using electromechanical sensors present in smart phones through a disposable cartridge. The temperature regulation of the device is done after loading the cartridge into the portable device so that there is proper amplification of the sample to the extent that the DNA can be identified and the whole process is about 30 min long. The microcontroller present in the smart phone transfers all the data of the patient to the smart phone app through Bluetooth. In case the result is positive a report detection along with the relevant data and location is sent to the cloud network which is then further displayed online. Figure 1 shows the samples of the patient tested o the cartridge. The results are then shown at the cloud network when the

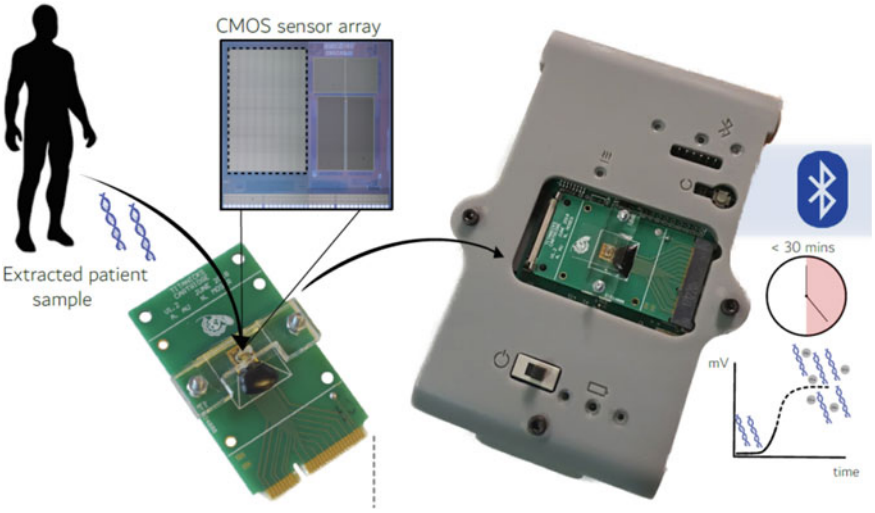

Fig. 1 Test results in cloud network through smart phone

smart phones receive the test via Bluetooth [13]. The device was successfully used for the detection of dengue virus in 2018 in Taiwan where the clinical samples which were stored were used for detection. The same was also used to detect the malaria causing parasite in 2019 in Kenya. Many researches have been done by the scholars in various countries to use smart phones as a medium to screen the patients infected from any virus, parasites or bacteria.

Talking about the virus which causes the infectious disease COVID-19 CoV-2 SARS the cartridge for storing the clinical samples can be developed once the sequence of the genetics is available publically. These could be then used to provide the tests very fast at an affordable price which can prove quite significant in detecting and monitoring the outbreak of this disease. Figure 2 shows the geo-tagged test results which are tracked on the cloud network.

3 Combating Covid-19 with Artificial Intelligence/Machine Learning

There has been a lot of development in the field of automation and artificial intelligence in the medical sector and has set revolution in this workspace. Half of the activities carried out have the ability to get automated and there is impact on all the other fields as well. Artificial Intelligence in health sector means that the patients who require care are diagnosed and treated using automated machines and process. Since it seems like the diagnosis and treatment are quite simple steps there are so many unseen background factors to be taken care of to properly treat the

Fig. 2 Cloud server displaying the geo-tagged test results

patient [14]. These unseen factors include: data collection through various modes such as calls and interviews; results are processed and analyzed; accurate and proper diagnosis id done using multiple sources of the data; the treatment methods which seem accurate are determined; the treatment method to be chosen is prepared and administered; continuous monitoring of the patient and the aftercare which includes follow-up appointments [15]. The time taken in the data entry by the workers was consuming a lot of time which could be rather engaged with patients. Therefore, the automation in the health care and medical fields should not go excessive but should go in a progressive manner so that the doctor–patient bond is still alive and strong. There is a need of sensible and deliberate identification of the areas where the time and effort of the workers is relaxed using automation [16]. The proper and effective balance should be maintained with the technology and artificial intelligence as well as with the trained judgments and strengths of the humans in medical professionals. The technology and automation play an incredible role in the field of medicines already such as digitization of medical records, scheduling online appointments, using of smartphones by the user for the nearest healthcare clinic and many more [17]. There are many examples of artificial intelligence which are already being used and deployed in the field of medicines. These include decision support system: this system gives the list of diagnosis possible for the given symptoms, information system for laboratories: the infections of the patients being hospitalized are detected, tracked and investigated in this system, robotic surgical systems: this system allows the doctors for precise surgeries with the help of magnetized vision and robotic arms which is

difficult using manual approach, therapy: artificial intelligence therapy is the online course for dealing with social anxiety, reduction in human error: the appointments could be booked by the patients through online apps present in the smart phones [18]. This also includes online consultation with the doctors for monitoring the routine and day to day health and provide test kits accordingly. Artificial intelligence in a way helps the medical sector to move towards better solutions, diagnosis and treatment in a precise manner. There is an increase in the productivity and efficiency other than reducing manual errors by incorporating artificial intelligence. Since artificial intelligence has come a long way in the medical field in combating the viruses it can surely be employed to combat the major pandemic of COVID-19 disease. Figure 3 shows the concept of incorporating artificial intelligence in the medical health care sectors.

The biomedical sensors on the patients imply that the smart phones carried by the patients progressively record and store the symptoms of the patient in the form of data. This data is then transferred to the cloud network through Bluetooth with the help of sensors present in the smart phone. The concerned healthcare community is also connected to the same cloud network. The data from the sensors present in smart phones and the mobile healthcare community is recorded on the cloud network. The clinical information system sends the information about the diagnosis and treatment of the disease to the clinical decision support system which is connected to the cloud network directly. This sends the data containing information about the possible diagnosis and treatment to the cloud. The doctors are also connected to the clinical decision support system to provide the accurate and efficient treatment to the patients. In this way the artificial intelligence plays a vital and significant role in the medical health care sector by reducing the efforts and time manually.

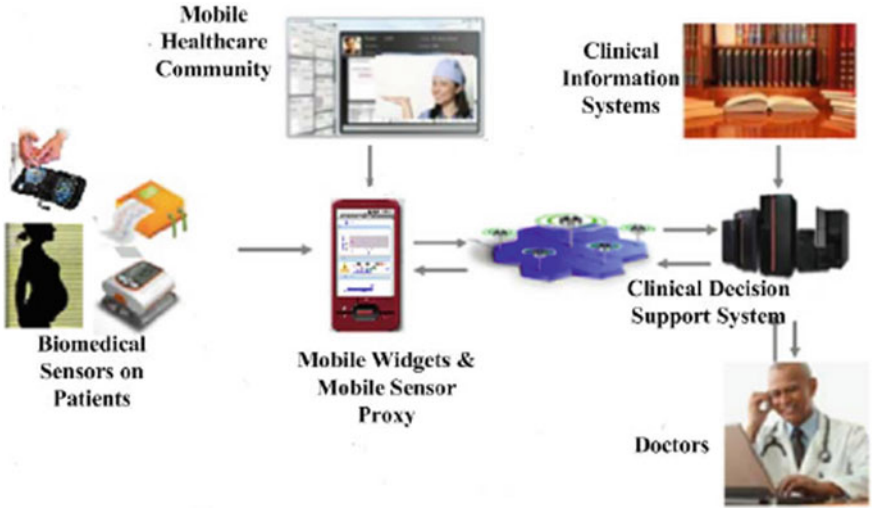

Fig. 3 Concept of artificial intelligence in medical sector

The critical thinking and intelligent behavior is simulated using with the use of computers which is comparable to a human resource. There are many kinds of artificial intelligent techniques which are employed in the health care sectors such as fuzzy expert systems, artificial neural networks, Bayesian networks and a lot more [19]. Since 2016 healthcare sectors have experienced biggest contribution of artificial intelligence research as compared to any other sectors. Artificial Intelligence in medicines has two types which are virtual and the other one is physical. The electronic systems for recording and the guidance in treatment based on the neural network systems come under the subtype of virtual category. The robots helping in surgeries come under the physical subtype. The basic idea is to correlate the clinical insights with the patterns already available in the information stored at the database [20]. Statistical methods are employed to establish the associations and patterns. Flowcharts and algorithms are being made by computers for database approach in the treatment and diagnosis of the patient. The flowchart includes the questionnaire by the physician to take a medical history record of the patient for providing a suitable diagnosis based on the complex systems presented by the patient. The cloud network which is machine-based stores and feeds large chunks of data which is considered later for the routine practice and treatment of the patient. But there are some limitations such as some symptoms are not identified by the machine which can be done physically by a doctor. The deep learning principle is utilized in the database approach in which there are repetitive algorithms for identifying certain symptoms and radiological images [21]. To combat the COVID-19 disease, artificial intelligence will play an essential role since it has already been utilized in many public health sectors and have created a large impact in every sector of medical field. This will help to diagnose the CoV-2 SARS virus in a short span of time so that the patient is quarantined timely and the community spread is reduced [22]. Figure 4 shows the flow diagram of employing artificial intelligence in the form of sensors in our medical departments.

4 Proposed Smartphone Based Framework

The detailed design is presented based on the proposed approach. A framework based on the smart phones is elaborated. The embedded sensors, algorithms and flowcharts are discussed in the proposed framework; the sensors embedded in the smart phones are used to associate the algorithms in order to diagnose COVID-19 corona virus disease [23]. Though many techniques and tests have been available as discussed in the previous section to diagnose COVID-19 but the method described in the given proposal is user friendly, cheap and readily available. Radiologists can use the solutions anywhere and anytime in their smart phones in case of emergency situations. Firstly, the symptoms of the suspected COVID-19 patient should be detected correctly [24]. The symptoms of this disease are very common which include fever, breath shortness, dry cough and pain in the muscles. Each symptom can be differentiated as these are the same symptoms for common cold and flu. The sensors available in smart

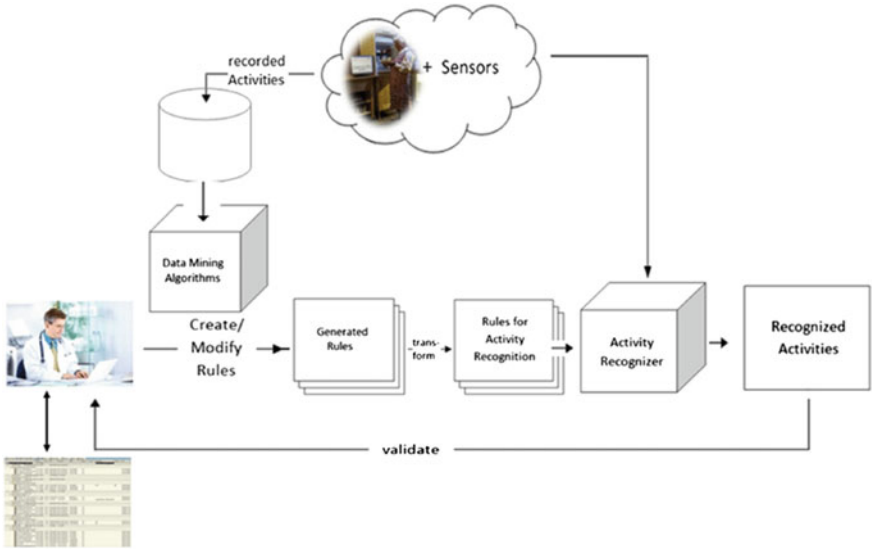

Fig. 4 Flow chart to identify the virus

phones today are able to take the input and can be made to measure the level of all symptoms in the proposed framework. The smart phones are embedded with many technology sensors such as temperature control, heart rate sensor, proximity sensor and microphones [25, 26]. The symptoms of the corona virus disease should be easily sensed by these technologies. Each sensor reading has the application of different algorithm owing to the different symptoms of the disease. For example fever can be detected with the help of fingerprint temperature sensor present at the rear side of the smart phone [27]. The human fatigue can be detected using the features of camera such as images and videos. The accelerometer sensors can also be used to detect the fatigue in the patient. Person is asked to take sit-ups for 30 s and total sit-ups can be counted using image processing and the activity can be monitored. The observations made in the video of the smart phone can be used to predict the level of nausea. The neck posture and the headache level can be predicted using the camera and inertial sensors embedded on the smart phones. Also samples of Lung CT scan and X-ray of chest can be uploaded. The microphone sensor can be used to identify the cough type whether it is dry cough or not. Heartbeat of person can be recorded through heart rate sensor available on smart phone. The above-mentioned algorithms and sensors are used in the proposed framework. After gathering the results and predictions of the symptoms using the sensors, the data is collected and stored as a record [28]. After collecting the records and data from various patients, they are used as inputs to the various techniques of machine learning. The techniques of machine learning in the medical field includes neural networks and *k*-nearest neighbor. There are various deep learning methods in the machine learning techniques which are quite accurate and comes under the family of neural networks. CNN and RNN are the

two main algorithms for deep learning which are used for the purpose of recognition and classification [29]. Here, CNN stands for convolution neural network and RNN implies recursive neural network. The neural method which is feed forward is called CNN and is mostly used for recognizing the images whereas there is a different concept for RNN. In RNN, the next layer input will be the output of previous layer being saved. The measurement of signals and test is mostly done by RNN. CNN is used for spatial data whereas RNN is used for saving the temporal data [30]. Figure 5 shows the proposed framework which contains different set of layers. These layers are reading layer, configuration layer, symptoms prediction layer and COVID-19 prediction layer.

The function of the first layer is to read the data stored in the sensors. For example, the CT scan of lungs, X-ray of chest, videos captured in the smart phone (camera sensor), and measurements from inertial and accelerometer sensors by sit-stand, measurements recorded through microphone sensor to identify the cough, heart rate can be recorded using heart rate sensor and the fingerprint sensor to measure the degree of temperature. All the readings of the sensor are identified in the first layer itself. The sensors present in the smart phone are configured in the second layer of the framework. This includes the intervals during the readings, size of the image, time resolution and so on [31]. The applications in the smart phones run the algorithm input to which are these configurations and readings in the first two steps. The level of the symptoms such as abnormal sub-image shapes, nausea level, fatigue level, cough

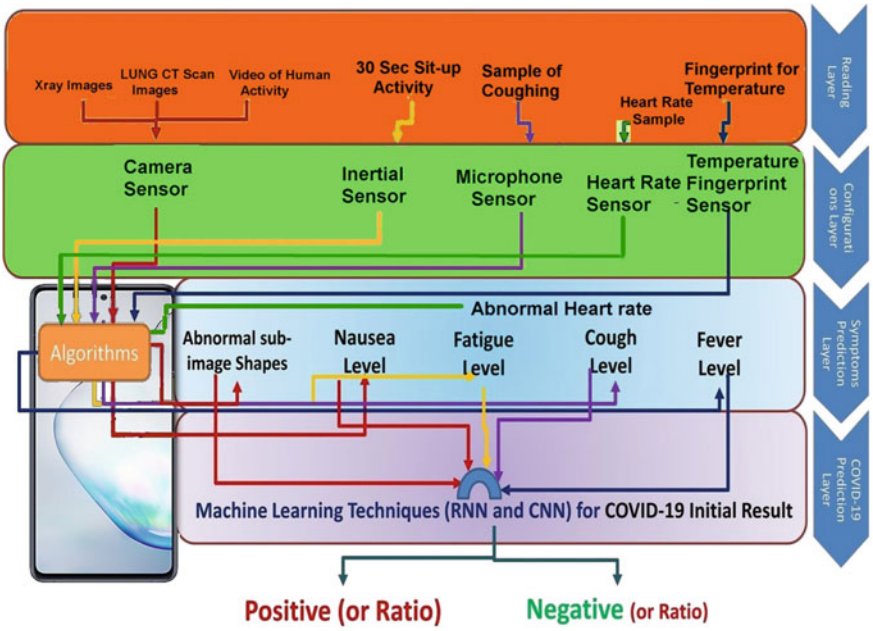

Fig. 5 Proposed framework to predict COVID-19

level and fever level are calculated in the third layer of the proposed framework. The symptoms are recorded separately and are stored for the input in the upcoming layer. The techniques of the machine learning are applied in the last layer of the framework which is used for the prediction of COVID-19 corona virus disease. For example, if the CT scan images are not normal then the CNN is used [32]. The last layer predicts the initial result for COVID-19 using CNN and RNN techniques of machine learning. The progressive CT scan images of the lungs is shown in Fig. 6. The key technique for detecting the COVID-19 disease is the CT scan. The increase in the volume and density of CT scan images is the evidence for confirmed COVID-19 case. The proposed framework allows the radiologists to efficiently decide the suspected cases which would otherwise take longer time if done manually by the radiologists.

Using deep learning the COVID-19 can be predicted using X-ray images. The epithelial cells of respiratory systems are affected by presence of COVID-19. So, X-rays can be used to analyze the presence. The dataset of X-rays of normal people and X-rays of COVID-19 people can be used to train the model and with the use of CNN and deep learning, the model will be able to detect the presence of COVID-19 virus in X-ray [33]. Figure 7 shows the X-ray dataset of normal and COVID-19 positive people and Fig. 8 shows detection of COVID-19 using algorithm.

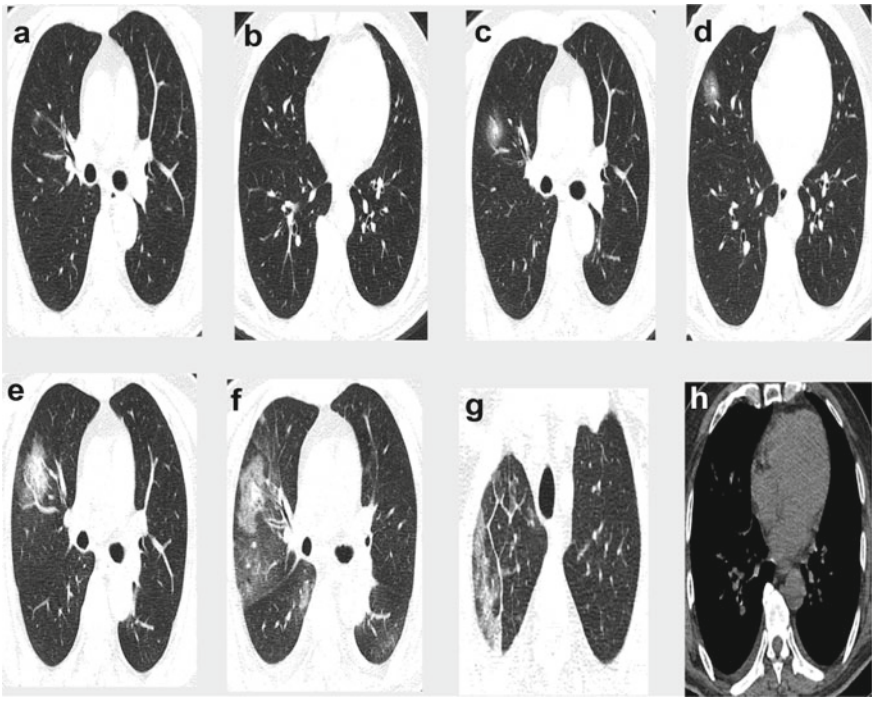

Fig. 6 CT scan images of a suspected COVID-19 case

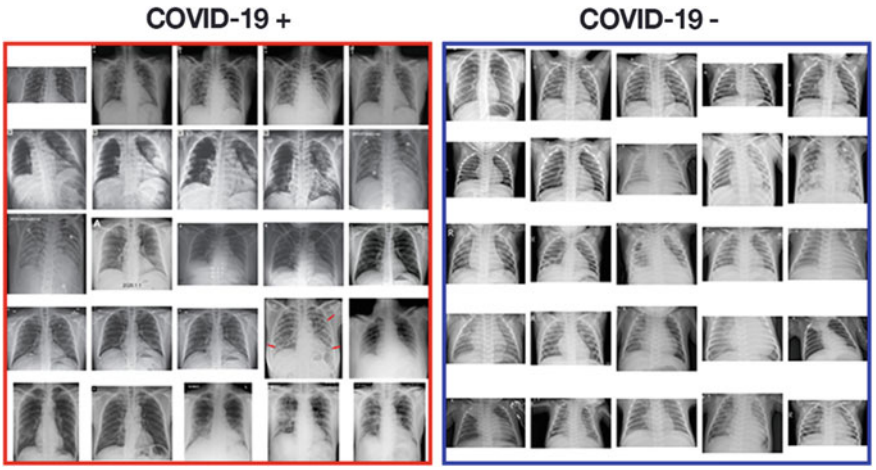

Fig. 7 Dataset of normal and COVID 19 people

Fig. 8 Detection of presence of COVID-19

The merging of artificial intelligence with cloud computing has manifested great results in the health sector. The models of the machine learning are generated to apply huge data to the algorithms and in order to store the data, cloud network is required. Variety of data obtained make different patterns which are identified by the models used in the machine learning. The accuracy and prediction of the framework is improved if more data is provided to the model. To identify the presence of virus in the lungs through CT scan images and in X-ray of chest many [34–36] reports of radiology should be trained in order to get a better diagnosis. The industries can use this pattern of images and records which are obtained as inputs in different forms like unstructured data and raw data. Since the computational techniques have become

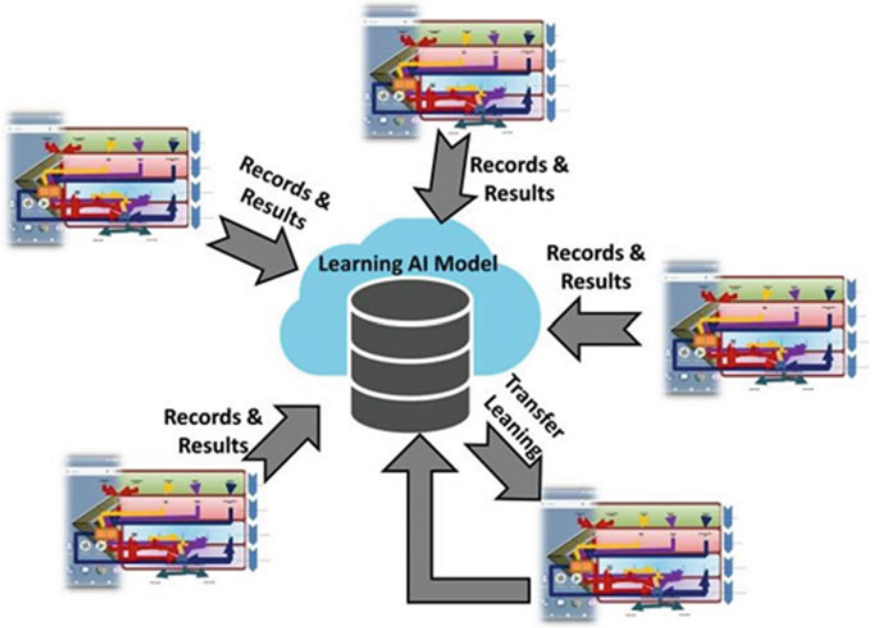

Fig. 9 Cloud network for the proposed framework

very advanced, CPUs and GPUs are required which are provided by the cloud in the form of virtual machines [37].

The automation of various tasks of machine learning is done with the help of various services such as server less computing, batch processing. The predictive analytics are also handled quite effectively through the automation. There are many benefits of combining artificial intelligence with cloud network through smart phones. These benefits are increased productivity, reliability and availability of advanced infrastructure [38–43]. Figure 9 shows the learning AI model in which different records and results from various patients are stored. To have a quick access to all the records, the merging of artificial intelligence with cloud computing plays a major role. The data from the AI models is also transferred for further progress through the cloud network. This type of framework can effectively use to combat the pandemic disease COVID-19.

5 Conclusion

In this paper, the detailed discussion about COVID-19 corona virus disease and the techniques to combat it. The symptoms, cause and the tests are broadly discussed and elaborated. Various radiology techniques, CT scan imaging, medical kits and modern

technologies are discussed. CT scan and PCR (Polymerase Chain Reaction) which are the tests for the diagnosis of COVID-19 virus in the human body are discussed. An anti malarial drug called has a very significant inhibitor effect on SARS-CoV-2 virus. This drug was not recommended for the patients showing symptoms of pneumonia. The solutions which are available currently have less accuracy, takes longer time and are costly. Artificial intelligence in a way helps the medical sector to move towards better solutions, diagnosis and treatment in a precise manner. There is an increase in the productivity and efficiency other than reducing manual errors by incorporating artificial intelligence. Since artificial intelligence has come a long way in the medical field in combating the viruses it can surely be employed to combat the major pandemic of COVID-19 disease in this paper, a framework is proposed based on smart phones and artificial intelligence which do not have the above mentioned issues. This framework can prove to be quite reliable as it is solely based on the measurements done by the sensors embedded in the smart phones. The radiologists and doctors can easily use these measurements anywhere and anytime on their smart phones. The proposed framework can also run in the applications of smart phones since no additional sensors are required which makes this framework more accurate and reliable. There are four different layers in the proposed framework which are reading layer, configuration layer, symptoms prediction layer and COVID-19 prediction layer. There are multiple readings in the sensors of the framework which refer to the various symptoms making this framework more reliable.

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