An Effective Diagnostic Framework for COVID-19 Using an Integrated Approach

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Abstract The coronavirus, one of the deadliest virus erupted in Wuhan, China in December and has claimed millions of lives worldwide and infected too. This virus has off-late demonstrated mutations thus making it difficult for the health professionals to adopt a uniform means of cure. Many people due to lack of support have confined themselves at home. The hospitals too are running short of equipment and support systems. Thus, computational connectivity between the patients at home and the hospitals needs to be established. The objective of this paper is to propose a framework/model that connects all the stakeholders so that either in regular monitoring or in emergency cases help can be provided to them. It has been well established through research and case studies that critical factors associated with this disease are oxygen level (SPO2), pulse rate, fever, chest infection, cough causing choking, and breathlessness. Data shall be collected, stored, and analyzed for the above symptoms and for this cloud storage and blockchain technology would be used. It has been established through various studies that non-clinical techniques like AI and machine learning prove to be effective for the prediction and diagnosis of COVID-19. Using this theory as the standard basis, machine learning models like SVM, Naïve Bayes, and decision trees can be used for the analysis, diagnosis, and prediction. Using IoT and its variants, remote monitoring of patient, and consultation can be provided

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to the patient. Appropriate action would be taken. In addition, a mobile application would enable the patients to gather or read about experiences of other patients. Thus, it would be established through the proposed framework, that an integrated approach of technologies has a great potential in such applications and offers several advantages.

Keywords Coronavirus · COVID-19 · Artificial intelligence · Blockchain · IoT · IoMT · CIoMT · Disease diagnosis · Treatment · Prediction · Mobile application · Smart health care

1 Introduction

Virus, a microscopic agent, are found in water, air, and soil. Common cold, flu, cough are the common infectious diseases caused by the virus. They enter our body and replicate through the normal cells, thus destroying them and make us sick. It largely depends on the immune system of our body, and the ability to fight with the virus or cause damage to us. When this virus spreads across at a large scale, worldwide disrupts the normal functioning of lives, which causes social and economic imbalance, and kills or infects lakhs, then the virus is termed as "pandemic virus". But for any viral infection, it is understood and medically proven that virus cannot be treated through antibiotics. Rather antibiotics work only for fungal or bacterial infections. This virus has found to be spreading more for some centuries now [1]. And the one that caused mass deaths was Spanish flu [2].

Coronavirus is another pandemic virus that was first reported in Wuhan, China in December, 2019 [3]. But, sadly was declared a pandemic only in [4]. Common symptoms of COVID-19 are similar to common flu which include fever, dry cough, sore throat, tiredness, body ache, and breathlessness (resulting in chest pain) [5].

Infected persons range from asymptomatic to those who show mild symptoms (say low-grade fever, mild cough, and tiredness) to those who show extreme symptoms which include drop in oxygen levels at several points of time and chest pain. The first category of asymptomatic patients are generally quarantined at home or at govt. run health-centers in absence of caregivers. The mild symptoms patient too can be remotely monitored at home or rushed to hospitals only in case of emergency if the parameters vary drastically. The third category is generally kept in hospitals to reduce the mortality rate and provide a life-saving support to them through physical monitoring by the health-care professionals. But, if the patient already suffers from acute or chronic illness like diabetes, respiratory diseases, or any type of respiratory or cardio-vascular disease then utmost care and regular attention and monitoring becomes a matter of concern. The severity and care may vary depending on the age [6] of the patient. Research works related to COVID-19 have been contributed and throw more light on various aspects related to pandemics which include pandemic prediction [7], drugs and medicines used [8–10], monitoring of the patient [11–13], and early detection and diagnosis [14–16]. This virus has indeed opened avenues for

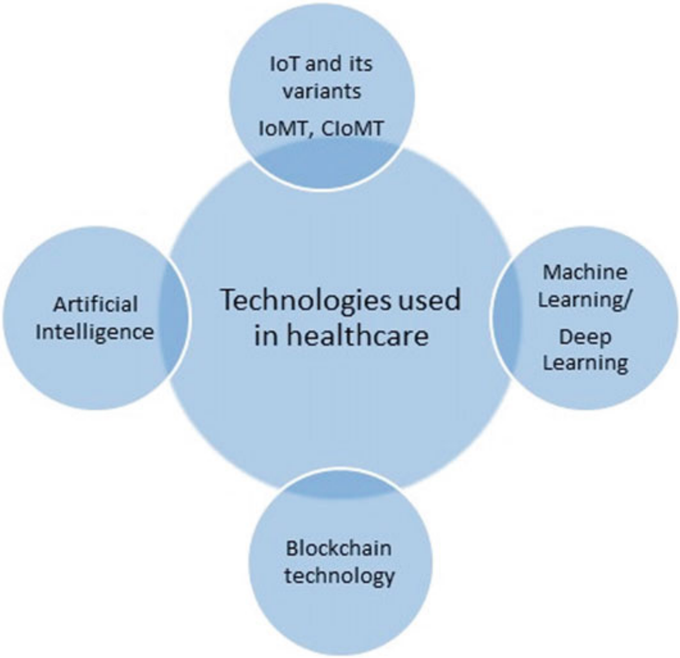

Fig. 1 Technologies related to health care

inter-disciplinary research where applications of science and technology in health care [17, 18] are much needed. These technologies as shown in Fig. 1 include big data analytics, machine learning, deep Learning, artificial intelligence (AI), IoT (Internet of Things), and its variants like IoMT (Internet of Medical Things), CIoMT (Cognitive Internet of Medical Things), and blockchain technologies. Some other works related to technologies and the area of focus in health care are mentioned in Table 1.

Currently, we all identify the best utilities of each of the technologies: IoT, blockchain, machine learning, and others. But no integrated framework exists that establishes meaningful relationships between each of them and can be used for translating the relationships into a form that would benefit the stakeholders of the health-care sector. IoT and its variants for data collection, blockchain for effective and secure data management, and machine learning for disease diagnosis by relying mainly on data and medical imaging, and Tele-health/ E-health for monitoring are effective techniques. This paper shall suggest a framework/ architecture that captures the essence of each of these techniques with a holistic view. This paper performs extensive research related to technologies related to health care, particularly, for COVID-19 in Sect. 2. Section 3 contains the proposed framework which adopts an integrated approach of several technologies so as to improve the health-care services, and its advantages are then discussed in Sect. 4. A conclusion of the paper is presented in Sect. 5.

Table 1 Research work related to technologies used and the area of focus

Reference No.	Area of focus	Technology used
[19]	Prediction	BP neural networks
[20]		ARIMA model
[21]		LSTM networks
[22]	Classification of confirmed cases and others	Artificial intelligence and regression analysis
[23]	Patient monitoring	Deep learning
[24]	Diagnosis and treatment	CT images-based deep learning approach
[25]		Blood tests-based machine learning approach
[26]	Remote health monitoring	A get-well loop program developed
[27]	Disease tracking	Data collection from mobile phones
[28]		Tracking app. Also includes a list of apps and some salient features of these apps for several countries around the globe
[29]	Drug discovery	Science and technology
[30]	Can be used for both treatment and remote monitoring	Sensor-based technology
[31]	Disease treatment	Blockchain technology
[32]	Reducing the workload of health-care workers	Artificial intelligence
[33]		Holistic view

2 Literature Review

Lot of research has been carried out related to COVID-19 and in particular on how to obtain the maximum benefits of using computing techniques for its prevention, prediction, cure, and remote monitoring. This section explores some of the related research work.

In this paper [34], the authors have examined the performance of deep learning algorithms with that of clinicians using medical imaging. Medical images have now been used for deep learning research. Particularly, convolutional neural network (CNN) take raw data as input, this network learns and develops its own representations for pattern recognition. Minimizing human interventions for feature selection, this network uses its own knowledge for feature selection depending on its importance and relevance. The measure of adherence to reporting standards, CONSORT for randomizes trials, and TRIPOD for non-randomized was used. Assessment of risk bias was done using Cochrane for randomized study and PROBAST tool for non-randomized study. Results related to these tools has been discussed in this work.

This paper, [35] used various classification models for identification of infected COVID-19 patients from the non-infectious ones to curb the spread of the disease. The study has been conducted using the X-ray images as the source data. The deep features are used for the classification. The data repositories include GitHub, Open-I, and Kaggle. A comparison of ResNet 50 and SVM with other classification models establishes this model better in terms of validation measures like F1 score, MCC, FPR, and Kappa.

Apostolopoulos and Mpesiana [36] proposes deep transfer learning (deep learning based) technique, for the prediction of infected COVID-19 patients automatically. 50 chest X-ray images of infected persons from GitHub repository and 50 chest X-ray images of healthy persons from Kaggle were used. As compared to three models used, it was shown through their study that ResNet50 achieved higher accuracy and can be used for early prediction for better performance. IoT and its applications in the health-care sector have been discussed in [37] this paper. Issues, solutions, and opportunities related to IoT and Health-care sector are discussed extensively. The authors also emphasize that IoT can be useful to governments in identifying solutions to problems that health-care sector faces and on a larger scale can benefit the society. Several works related to IoT and Health-care are discussed in [38–43]. AI has been used extensively in several sectors including the health care. In particular, its contribution in dealing with the pandemic COVID-19 has been extraordinary. Researchers are harnessing its benefits for prediction, detection, classification, cure, and diagnosis. 13 groups of problems related to the pandemic are identified and AI can be used for finding solutions to these problems. Data sources related to corona are presented in [44] for future use and research. The authors discuss that use of blood tests, chest X-rays and CT scans [30] are the methods being adopted worldwide for the detection of the novel coronavirus. But the need is to provide low-cost solutions for the same. To enable this, they propose an AI-based framework which is uses built-in smartphone sensor-based technology for the disease detection. They emphasize that since smartphones are a day-to-day utility owned by all, so the sensors installed in smartphones would provide data which can be analyzed and processed for identifying the severity of the disease. An AI-based framework has been suggested in [45] for the identification of COVID-19 cases. The framework uses survey data gathered through smartphones when people cannot move out of the houses as cities are under quarantine.

In this paper, [46] authors extensively examine the trends in China and suggest a model, namely Susceptible-Exposed-Infectious-Removed (SEIR) for deriving epidemic curve. This helps to correlate the peak of cases and the fall with time. They have also suggested an AI approach, for the prediction of the epidemic. This study [47] proposes and generates compounds against SARS-COV-2, using a drug discovery pipeline which is deep learning based. Identification or screening of patients at an initial stage [48] is achieved in this study using a deep learning approach. CT images/scans are used as the basis for distinguishing coronavirus patients from Influenza-A pneumonia and these from the normal ones. Through this work, they have explored CT images as an important diagnostic tool for this identification and can be helpful for the clinical trials by the doctors. A deep learning-based approach called COVIDX-Net [49] has been proposed in this work. This approach uses X-ray images as the diagnostic tool which can help the radiologists in identification of COVID-19 patients. A few classifiers have been used for the experiments and for evaluation. The study [50] aims at early detection of coronavirus using machine learning techniques. Abdominal CT images were used for this study and analysis. Since, COVID-19 exhibited different behaviors from viral pneumonia, so detection of coronavirus becomes essential. Patches of different sizes from 150 images were taken. For classification, feature extraction was then applied on these patches. Four different algorithms were used for feature extraction. Assessment of results was done using several parameters which include precision, f-score, accuracy, sensitivity, and specificity. The best results were obtained with gray level size zone matrix algorithm. The next section discusses the framework that would be effective and improve the health care particularly for the COVID-19 infected/ suspected patients.

3 Proposed Framework

The proposed architecture encompasses the advanced technologies as discussed in Fig. 1 at various steps and suggests how integration of these techniques for various domain applications like diagnosis, storage, prediction, circulation, treatment, and cure can help us develop a model well-suited for all in the current situation. The steps of the model are mentioned below.

Step 1. Data collection: Wearable technologies can incorporate sensors which be used for capturing acoustic information (volume and frequency), biological information (temperature, heart-rate, fatigue, stress, and respiration rate), optical information (brightness and refraction), and other environmental information (temperature and humidity). Data using biological sensors various important symptoms which include ECG monitors, pulse oximeters, fatigue, cough, fever, and tiredness. Techniques for these are discussed in [51–55]. Other parameters like travel history/get-togethers or meetings attended along with the dates would be collected. Other data collected using input from the end-user would be personal details (age is an important parameter), and medical history with critical ones being diabetes, blood pressure, and heart disease.

Step 2. Data storage: Thus, we understand that there are broadly two types of data: personal data and electronic health records. All the data collected (known as Data Lake), is then encrypted, digitally signed and then stored as a health blockchain. Each digital record also stores the location of the health data it references. It also contains the patient's public ID. The patient's private key links their identity to blockchain data. The private key can be shared with health organizations if the person desires by giving desired access permissions. Using this key, the data can be decrypted to uncover the original patient's data. Blockchain offers advantages (most relevant being security, privacy, and accessibility) that can revolutionize the way health-care sector works, so it can be harnessed for data storage and data sharing [56] as well.

Step 3. Data preprocessing: As discussed, in Step 1, the data collected would be heterogenous in nature and may have several features which may be irrelevant. Thus, conversion of data to a standardized format, reducing the size by selecting interesting data [57] and removing of outliers are performed as part of this step.

Step 4. Disease diagnosis, treatment, and cure.

Each of the patient would fall any of the three cases:

- Suspected (through contact tracing would be quarantined in centers/or at homes).
  Through live streaming of CT scans and X-ray images further processed by AI-based sensors can help the lab technicians for further analysis. If they show symptoms in about five days, which is the average incubation period, then would become the confirmed positive and dealt accordingly.
- Confirmed positive (depending on age and other related ailments and depending on severity of disease would be either kept at home or sent to hospital). If kept at home then, a government physician can be assigned and local dispensaries can monitor the health. Remote health monitoring techniques using CIoMT can be used. Patient feedback and response can be used for effective treatment using CIoMT. Also, geographically driven real-time identification of positive cases can be done as the health-care units are connected via IoT. Mobile apps giving updated information area wise about houses or people reported as positive using IoT. Drugs/medicines delivery can be ensured by the blockchain companies. If critical parameters report an absurd rise or fall, then will be sent to hospital.
- Confirmed negative No major action needs to be taken. Just precautions need to be continued to prevent the disease from infecting this person. Not only prediction, the model can be used for identifying the treatment response which can then be utilized to treat other patients by self-learning and by self- adaptation.

Machine learning models like SVM, decision tables, and neural networks can be applied for the disease diagnosis. The reason for choosing machine learning models are plenty. Machine learning, an advanced concept of AI, gives strategic way for the development of complex, algorithmic methods and uses statistical techniques for bio-medical data analysis. Then hidden patterns or knowledge can be extracted from past experience. Performance evaluation of ML models is then followed by its optimization by using new rules. In [58], the authors used various ML techniques like decision trees, logistic regression, support vector machine, Naïve-Bayes for prediction of COVID-19 infection for negative and positive cases of an epidemiology dataset for patients based in Mexico. It was shown through experiments that with respect to accuracy, decision tree was the best among others. It also indicated that age was an important feature among other features. The model also indicated that those suffering from chronic diseases like diabetes, hypertension, asthma, etc., are likely to be infected. Also, males are more prone to the infection than women. Also, this study proved that decision trees help with the diagnosis of suspected COVID-19 patients. Another study [59–62] also proved that decision tree model is best suited for diagnosis and also for predicting the possibility of recovery of COVID infected patients. These

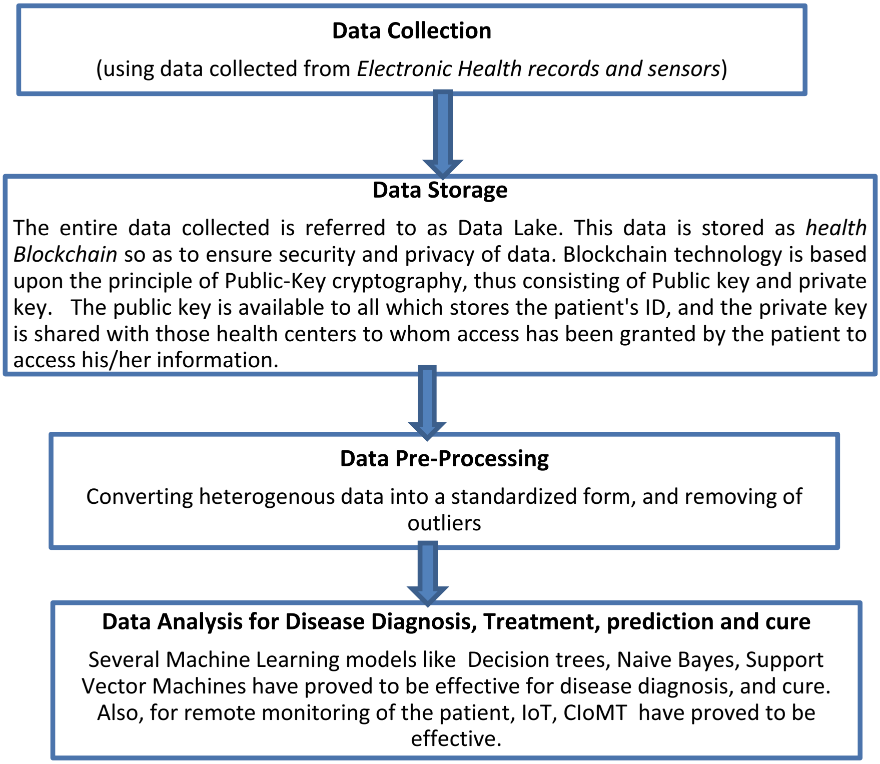

Fig. 2 Proposed framework

studies were used as the basis for choosing ML models for the diagnosis and recovery in the current study. Figure 2 depicts the proposed framework.

Other prominent features of the framework are:

- A restricted entry to the hospital/ quarantine centers can be ensured by making the entry points micro-chip enabled or eye retina-based entry would be granted to only authorized persons.
- The room would adjust the room temperature using a smart electrical system. This would not only provide comfort to the patient but also, reduce power consumption. An efficient energy management can be achieved using this.
- In case, a patient is old and incapable to talk to his family members or do video calls, then the nursing staff would mandatorily provide this service.
- The medical staff, especially in case of COVID-19 patients avoid visiting them to avoid infection. This would be monitored remotely by using AI-based approach which would ensure regular attendance monitoring of the staff.
- The clinical reports are not shared by the hospitals with the family members and only handed over to them at the time of discharge. As a result, they are unaware

of the real situation and health of the family member. Blockchain would ensure data sharing and enable the family members to monitor the health remotely and enable them to take second opinion from any other doctor if they want. This same process can be adopted for treatment and medicines being given to the patient. Also, sharing of readings of several important features like sugar level, blood pressure reading, pulse rate, and SPO2 can be shared with them. This would ensure transparency at all levels.

- A constant video monitoring of the patient's room should be ensured to swiftly identify deterioration in health and immediate support by the medical staff.
- The patients inside the hospital/ quarantine center would be given a wearable sensor. This sensor would continuously monitor critical parameters like SPO2, BP, sugar, and pulse rate. In case of any sudden rise or fall of these values, an emergency signal can be sent to the control room of the health center.
- Depending on the health condition of the patient and sensors which identify the taste habits of a patient, a personalized menu plan can be crafted and automatically updated with the approval of the doctor.

A mobile application that would connect people across the globe at one platform, and each one of them can share their journey of recovery with each other. This would not only help each other but also ensure a mental wellbeing using a digital solution [60]. It has been observed that not only, physical health monitoring of the patient, but COVID-19 can have a negative impact on the mental health too. Success stories of people around can motivate a person and bring positivity. These factors are as relevant and important in the recovery of a patient as are the physical symptoms.

4 Discussion

This framework does not work on any one technology related to health care, rather uses an integrated approach and derives the benefit of each one of them. In addition to the benefits that can be derived from the proposed framework, blockchain companies can be used for the timely delivery of medicine. Machine learning models (an efficient diagnostic model) can be effectively used for diagnosis and prediction. IoT, IoMT, and CIoMT, which create an inter-connected network of the stakeholders (like hospitals/government centers/nurses/lab technicians) can be used effectively to monitor the patient either remotely or otherwise. These technologies would trap the feedback and patient response for treatment. It would also help the doctors to swiftly and effectively respond to new cases encountered. The proposed framework would not only reduce the impact of the disease, the morality rate would be decreased and effective follow-ups can be done. A lot of research has been done related to COVID-19, yet, it lacks an in-depth and complete insight of several issues that stakeholders are facing in real world.

5 Conclusion

This paper has tried to visualize a framework which can be used for effective prediction, diagnosis, treatment, and cure. It will also help the physicians to effectively monitor new cases based on the learning capability of machine learning models. For future work, this framework can be implemented and can be used for handling COVID-19 in an effective manner. Advanced deep-learning models/techniques might prove to be more effective in future for tackling this disease. Effective drug discovery and vaccines, are the need of the hour. It has also been mentioned in the paper that there is a need of technological innovations that monitor the mental wellbeing of the patients. These are the challenges that open avenues for future research work.

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