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IoT based Health Monitoring & Automated Predictive System to Confront COVID-19

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***Abstract*—As the whole world is striving to combat the Coronavirus disease (COVID-19), healthcare and health monitoring systems are struggling to confront the virus. Many cases have been observed where the COVID-19 could not be identified at a specific time. Furthermore, any effective strategy that can monitor the coronavirus state in the human body has not been established yet. As a result, patients of the coronavirus could not receive proper treatment when necessary. Therefore, the death toll due to COVID-19 is rising. This paper proposes a systematic approach to combat the COVID-19 pandemic more efficiently by combining the concept of 'Internet of Things' (IoT) and machine learning (ML). The paper also gives a brief idea about how IoT can be used to monitor the health status and also to detect the severity of coronavirus in a human body by using some of the biological data such as body temperature, heart pulse, etc. from the patient's body. The developed system can provide healthcare, maintain distant communication, and emergency medical support to the patients. This paper proposes a practical solution with the help of the developed health monitoring system that can mitigate the loss done by the COVID-19.**

Keywords*— *COVID-19, IoT, Machine Learning, Embedded Multiple Sensors, Health Monitoring System, IoMT.

I. INTRODUCTION

The COVID-19 was first detected in the Wuhan of China's Hubei province in December 2019. In March 2020, the WHO (World Health Organization) announced the virus's massive outbreak as a pandemic [1]. Since the outbreak of COVID-19 at an enormous scale, most countries worldwide had been declared lockdowns by their decision-makers [2]. Such measures seemed necessary from the given perspective, yet at the same time, it has been causing a massive loss in the world economy. Most importantly, the outbreak couldn't be retained since its first detection in China. The continuous spread of the virus resulted in it becoming a pandemic. As of the second week of September 2020, the virus has affected 213 countries with an infected count of more than 29,095,917 people (with active cases above 7,226,376) and a death toll of approximately 926,824 human lives [3]. Such huge numbers could have been avoided if specific measures were taken and if proper health monitoring systems were used to treat these people.

On the contrary, most of these cases received no treatment at all. A theory has become quite established and proven that people with other severe illnesses are most likely to lose lives due to the COVID-19 infection. Therefore, there have been quite a few cases of great confusion about whether a patient is displaying symptoms because of the virus or symptoms of other diseases. This paper represents a brief idea to confront the spread of such an illness using the concept of IoT. The Internet of Medical Things (IoMT) is a corresponding field of IoT working in the sector of Medicine & Biology. Such a research field can be helpful in the fight against COVID-19 and can avail healthcare service to the patients remotely where possible. After the virus outbreak, some airports have used AI to detect suspected COVID-19 cases on humans through image processing, thermal scanning, computer vision, and Big Data [4].

For humans to confront a pandemic like COVID-19 requires to not be in physical contact with the infected persons. This is the scenario where the proposed system can be implemented to reduce the risk of the healthcare service providers getting infected as well as being able to respond effectively in time. The goals of the developed system are set out to implement an effective health monitoring system for COVID-19 patients that can provide real-time biological information and also can establish a communication channel between the patients and healthcare professionals while maintaining a physical distance. Also, the system has been developed with the target to calculate the possible rate of coronavirus present in a person's body. The overall contribution of the paper can be summarized as follows,

- The paper represents a system that provides a brief idea of how an IoT based health monitoring system can be established to confront diseases like the COVID-19.
- The paper combines an ML strategy to predict the severeness of the patients. The data is aggregated using IoT devices, and the system can maintain real-time communication with the patients.
- The paper further validates the method using real-time data executed in the cloud platform.

The rest of the paper is organized as follows. In Section II, we explore other works done in this domain. In Section III, the architecture of the method is discussed. Furthermore, Section IV exhibits the approaches of cloud-based strategy and experimental setup. Section V provides an empirical analysis of our approach by applying different ML algorithms. Finally, Section VI concludes the paper.

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II. Related Works

Many novel research works have been conducted on health monitoring, which inspired us to develop the system represented in this paper. A research work carried out by Lifang et al. [5] shows a method to identify situational information propagated on social media, which can be used by the authorities to organize the social media posts relevant to a specific issue. This enables the authorities to respond accordingly to people living in a particular area predicted by the system. Such a method implemented in IoT can help the authorities to decide whether the people living in an area are aware and maintaining rules during the lockdown period. In another work, Mahmud et al. [6] explained an IoT project of a structural health monitoring system that was built with Raspberry Pi, ADC, sensors, WiFi module, etc. that can help monitor patients remotely. As the confirmed and suspected patients of COVID-19 are required to be in quarantine for at least 14 days [7], they need to get proper treatment from the experts only if they have symptoms. Thus, an IoT health monitoring system would enable the expert doctors to provide services and advice to the patients by monitoring remotely. Prabha et al. [8] showed an IoT-based rapid medical response plan designed for a smart-city. Sad et al. [9] displayed an architecture where raspberry pi worked as the main processing unit of a system with machine learning algorithms as well. Yanjun et al. [10] explained how the IoT and Data Mining framework could be used for motion intelligence and generate novel ideas based on the health nation plan. Jose et al. [11] explained a smart health monitoring system of daily human activities. Din & Paul introduced an IoT-based smart health monitoring and management system [12]. The model introduced by the authors is composed of three layers. In the first layer, the data is generated and processed. On the second layer, the processing of Hadoop [13] occurs. The last layer is the application layer. In another work, Nguyen & T. presented a survey on how the methods generated from Artificial Intelligence (AI) are being used in the research of COVID-19 [14]. Maghdid et al. proposed using sensors available on smartphones to collect health data, such as temperature [15]. Rao et al. focused on the analysis of data collection using online surveys and finding patterns in such data with the help of an Artificial Intelligent framework [16]. Fatima et al. proposed an IoT-based method to detect cases infected with coronavirus [17]. The architecture of the proposed model is based on a fuzzy inference system. Otoom et al. proposed a prototype model that is IoT-based, used for controlling blood sugar in real-time [18]. Alshraideh et al. proposed a diagnosis system that is IoT-based for patients with Cardiovascular Disease [19].

The health monitoring system that we have developed took inspiring concepts from all relevant research works carried out by the researchers. There have been some works on COVID-19 done by other researchers that used machine learning algorithms or IoT. But very few of those works were developed with a combination of both fields and they were not efficient in real-time. Our developed system embodies a real-time health monitoring system specially designed for confronting the COVID-19 with a combination of IoT and ML algorithms; which has not been observed in any other research works.

III. Methodology

The proposed health monitoring system in this paper has been designed with a combination of IoT features and ML algorithms with accessibility through a cloud-based network. The system has been developed to monitor the patient's health remotely using several embedded sensors. It has also been designed to predict the severity of COVID-19 based on the symptoms and real-time biological information.

A. The Architecture of the System

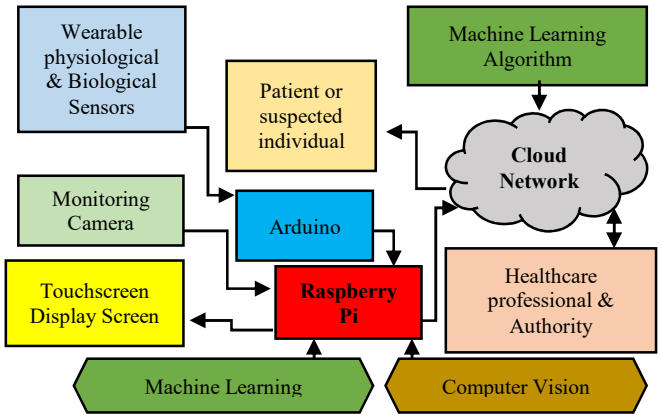

Fig. 1. Block Diagram Representing the Proposed System

The block diagram shown in Fig.1 represents a basic overview of the system. The individual blocks representing a specific part of the system which can be comprised of various types of devices fulfilling the targeted purpose. As shown in Fig. 1, the Raspberry Pi works as the central processing unit for maintaining the connectivity between the patient, the cloud network, and the healthcare professionals. The program for predicting the presence of the disease is implemented in the cloud network using ML algorithms. Different types of embedded multiple sensors are connected to the Arduino module, which is finally connected to the Raspberry Pi. The monitoring camera and touchscreen display are also connected to the Raspberry Pi. ML algorithms and computer vision techniques are used to train the Raspberry Pi for analyzing different types of data. In this particular system, we used OpenCV for developing programs in the Raspberry Pi. Healthcare professionals can get the analyzed data from the cloud network and send necessary instructions to the patients through the network as well.

TABLE I: Implemented Features & Devices of the System

Targeted Feature	**Scheme**	**Usable Devices/Program**
Data Collection Unit	Wearable Physiological Sensors	Heartbeat sensor
		Temperature Sensor
		Blood Pressure Sensor
		Moisture Sensor
		Infrared Sensor

	Environmental Sensors	Temperature & Humidity Sensor
	Monitoring Camera & Scanners	Pi Camera
Data Processing Unit	Initial Processing Microcontroller	Arduino Uno
		Arduino Nano
		Raspberry Pi
	Data Processing Feature	Computer Vision
		Machine Learning
Network Connectivity	Data I/O Process	WiFi Module
	Data Storage	Device Storage
		Cloud Storage

Table I provides a brief idea of the implemented devices and programs fulfilling the different schemes of the system. The physical sensors and processors work on collecting patient's biological data in real-time, and these data are passed to the Raspberry Pi, which then uploads these data to the cloud network using a WiFi module. The cloud platform further analyzes the data using ML algorithms. The healthcare professionals can then get the data from the cloud network and provide necessary instructions to the patient through it. The patients can get instructions from the healthcare professionals using two methods. First of all, they can access through the device as it can display instructions on the touchscreen display. Secondly, they can receive instructions directly from the cloud network by simply logging in to the server with the IP address specified for the device.

B. Embedded Multiple Sensors

The system has been developed to enable the collection of various types of biological and environmental data from multiple sensors. These sensors are connected to an Arduino module (which can be any type of microcontroller available, e.g., Arduino Uno, Arduino Pro, Arduino Nano, etc.). In Fig.2, we can see a simulation for these embedded multiple sensors being carried out in the Proteus simulation software.

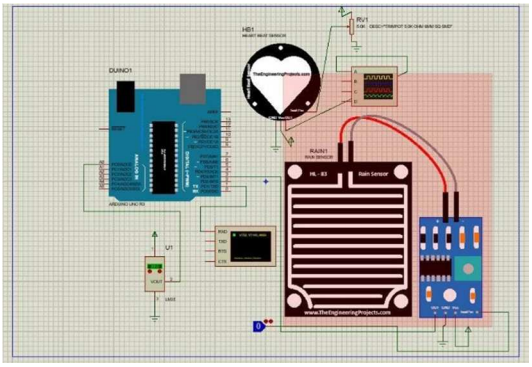

Fig. 2. Simulated Prototype of the Embedded Multiple Sensors

IV. Developed Cloud Network Model with Machine Learning Approach

Various compartmental models have been introduced to prevent pandemics like COVID-19. Compartmental models generally construct a simple mathematical foundation that projects the spread of infectious disease and detects the severity of the disease in the patient using external symptoms. Ordinary Differential Equations (ODEs) are the foundation of these compartmental models. ODE and other mathematical methods are sufficient in modeling an infectious disease, but they misjudge the randomness of being infected, cured, and dead. Therefore, we implemented an IoT based environment that solves these issues by uploading real-time biological data of the patient to the program developed in the cloud network. The sensors and processing units upload the data with a specific IP address for the particular cloud storage. These data are then taken into the compartmental model, which are then processed and analyzed.

A. Dataset

The proposed simulated dataset of COVID-19 consists of multiple symptoms observed in 316800 patients from different countries. These data were collected from hospitals and medical institutions all over the world that are fighting the coronavirus at present time. The symptoms in the dataset include body temperature, blood pressure, heart pulse, etc. which indicate the possibilities of patients having the coronavirus in their body. This dataset represents the data collected from the cloud storage of the proposed system. Most of the variables in the dataset are in binary format. The value of a feature variable being '1' means a specific symptom is present, and inversely, the value '0' means there is no symptom. On the other hand, the dataset's target variables describe the severity of a patient's condition in three categories, as mentioned below.

- None (No Severity)
- Low severity
- Moderate severity
- High severity

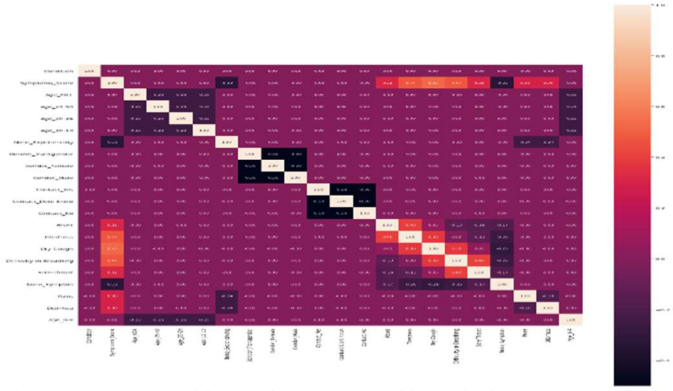

Fig. 3. Feature Variables And Target Variables Of The Dataset And The Relation Between Them.

A clear analysis of the relation between the feature variables and the target variables has been produced using feature engineering methods of the Pandas library [20]. This analysis is visualized in Fig. 3 using a heatmap produced with the help of the Seaborn [21] visualization library.

B. Data Pre-processing

In this step, we preprocess the dataset to feed the data to the Machine Learning algorithms. Firstly, we convert the whole dataset to a Pandas data frame structure. Then we drop less important feature values from the data frame. After that, both

the feature variables and the target variables are converted into arrays of floating-point numbers so that the algorithms can understand them. Besides, we also split the arrays into training and validation sets to properly evaluate the Machine Learning pipeline's performance.

C. Baseline Architecture

A supervised learning strategy is implemented to train ML algorithms. As the dataset contains binary values, regression models perform better in this case. Regression models are designed based on algorithms that analyze continuous data. The algorithms used in this step are state-of-the-art classifiers implemented using Scikit-Learn [22].

D. Evaluation Matrix

The evaluation of the proposed model has been done by the accuracy evaluation metric that is based on the confusion matrix. A confusion matrix abridges the outputs received from the prediction measuring the performance of the machine learning classification algorithms that are composed of four measures: true positive (TP), true negative (TN), false positive (FP), and false-negative (FN). The Accuracy shows how often the classifier is correct. Accuracy is calculated by the following relation,

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad \dots \quad \dots \quad (1)$$

E. Experimental Setup

In our cloud network model, Python is used for managing data, preprocessing, experimenting, and evaluating the model [23]. For further analysis and assessment, we have tested some neural network architectures implemented in Keras [24]. But they did not perform up-to-the-mark compared to the regression-based classifiers. Therefore, we have chosen to depend on the best performing algorithms. NumPy [25], a Python library, has been used to perform basic mathematical operations. TensorFlow [26] has been used to generate and control the whole pipeline's cloud infrastructure processing resources.

V. Results and Discussion

The proposed IoT based system has been structured in such a way that it can help to recover from the tremendous loss occurring because of the COVID-19 pandemic. The system is successful at achieving the goals which were set primarily. As maintaining the physical distance plays a crucial part in combatting the virus, the proposed approach enables the healthcare professionals to provide their service to the patients by monitoring them remotely. The proposed system can establish a low-cost health monitoring system with significant efficiency. Additionally, the feature that generates real-time data enables the authority and healthcare professionals to get notified in time to respond to a critical situation quickly. The proposed system also opens an opportunity to understand the patient's health better and provide proper treatment by getting information on the severity of COVID-19. Thus, patients with other diseases can be treated accordingly without the possibility of being mistreated. The embedded multiple sensors for the system were developed as a prototype and can be improved even more by adding other sensors. Fig. 5 shows the embedded multiple sensors implemented physically for the system.

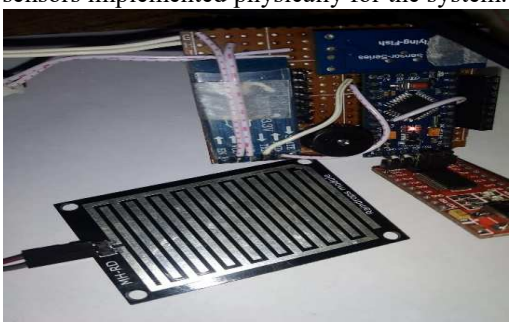

Fig. 5. Embedded Multiple Sensors Developed Physically for the System

During the training of the classifiers, 75% of the total data were used for training purposes and the rest were used for evaluating the performance of the classifiers. In Fig. 6 and Fig. 7, we can see the ML classifiers' metric performance scores at predicting COVID-19. From these charts, it can be understood that the logistic regression is the best performing classifier that indicates the probability of the presence of COVID-19 in a patient on our dataset with high accuracy. Logistic regression outperforms all other classifiers obtaining a training accuracy of 85% and a validation accuracy of 85.71%. In Fig. 6, we can see the resultant training accuracy of the classifiers, and in Fig. 7, we can see the classifiers' validation accuracy.

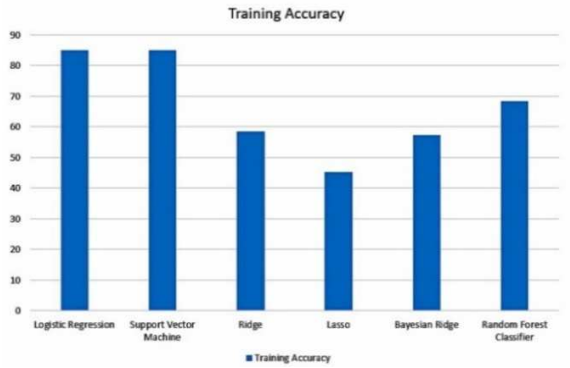

Fig. 6. Training Accuracy of Machine Learning Classifiers

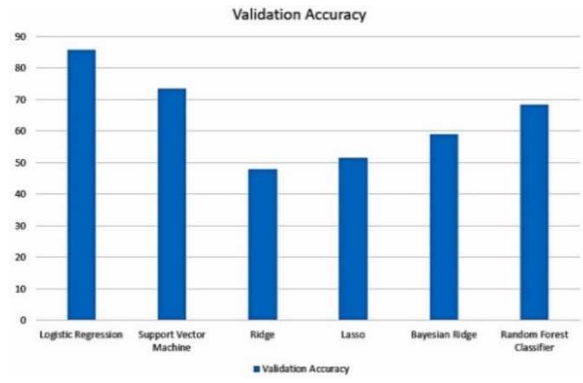

Fig. 7. Validation Accuracy of Machine Learning Classifiers

VI. Conclusion & Future Scope

The whole world is affected by the COVID-19 pandemic. The proposed IoT-based system can play a significant role in saving lives and be of great service in the health sector. It can be an excellent asset for healthcare professionals and the authorities to confront the virus. Infected and suspected cases can also get the necessary healthcare and can be adequately monitored by this system. As physical distance can be maintained with the help of the system while providing treatment, the risk of healthcare service providers to get infected from treating any patient can be reduced. The embedded multiple sensors showed excellent accuracy in detecting biological and environmental data. The processing units, i.e., Raspberry Pi, Arduino modules, can efficiently upload the data to the cloud network or cloud storage. The ML algorithms implemented for the system in the cloud shows quite a significant result. However, the size of our dataset was comparatively small. But with more data collected from COVID-19 patients, the dataset can be expanded to enable more accurate analysis and prediction for the proposed system. As per the future improvement, we are working on developing the system with more accurate biological sensors and improving the performance of the Machine Learning Algorithms. The proposed approach can be established at a lower cost but has a great promise to combat the coronavirus by providing proper treatment to the patient and suspected cases and responding to critical health situations. The developed device can be improved to use as a wearable device and it won't cause any harm to the health. Therefore, the proposed system can be considered as a great promise in confronting a highly contagious disease like COVID-19.

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