Design and Development of IoT Wearable Device for Early Detection of COVID-19 and Monitoring Through Efficient Data Management Framework in Pre-pandemic Life

M. R. Sundara Kumar, Ahmed J. Obaid, S. Sankar, Digvijay Pandey, and Azmi Shawkat Abdulbaqi

Abstract COVID-19 virus named CORONA is a vigorous disease spread all over the world very quickly and creates a pandemic situation to the human beings normal life. As per the doctors and researchers from the laboratory point of view, it will spread to a huge volume when humans are not followed certain principles. Moreover, this disease is easily transferred to neighbors and others in a short period which leads to death. To rectify the remedy for this virus, various spread countries and research peoples are creating the vaccines and some precautionary methods for living hood situation. Recent techniques are used to detect and monitoring the COVID-19–affected person's lifestyle and insisting they take precaution steps for early pre-pandemic life. IoT is a framework that is used to generate data from the human body from the sensors opted for human conditions. Wearable devices have been created with these sensors and communicated with human bodies directly or indirectly. The generated data will send through the server using any connectivity techniques such as Bluetooth or Wi-Fi. Analytics will be done at the server side for taking actions like the human body is affected by the COVID-19 virus or not. Finally, the generated data from a human can continuously store in real time in a cloud server which will be managed as a framework efficiently. This research work proposes a framework for data management in the early detection and monitoring of COVID-19 persons through IoT wearable devices in a pre-pandemic life. The experiments have been

M. R. Sundara Kumar (✉) · S. Sankar
Department of CSE, Sona College of Technology, Salem, India
e-mail: sundar.infotech@gmaill.com

A. J. Obaid
Faculty of Computer Science and Mathematics, University of Kufa, Kufa, Iraq
e-mail: ahmedj.aljanaby@uokufa.edu.iq

D. Pandey
Department of Technical Education, IET, Dr. A.P.J. Abdul Kalam Technical University, Lucknow, Uttar Pradesh, India

A. S. Abdulbaqi
Department of Computer Science, College of Computer Science and Information Technology, University of Anbar, Ramadi, Iraq
e-mail: azmi_msc@uoanbar.edu.iq

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done at different zones, and the results are shown symptoms of COVID-19 disease. Parallel work reveals the data management in a cloud server since data have generated continuously in real time and tracking details also stored genuinely. Data management is the typical process in this research because all the data were generated in real time and analytics will be done whenever required. For that large amount of space and effective retrieval technique is required for data extraction. This research work data set is derived from various Internet sources like government web sites and mobile applications, and then, results have displayed the COVID-19 disease details accurately in real time.

Keywords COVID-19 · Bluetooth · Wi-Fi · IoT · Cloud server · Framework · Wearable device

1 Introduction

COVID-19 virus affected the normal life of a human all over the world. In this digital era, new techniques and innovative ideas are used but early detection or assessment is not possible due to the lack of real-world application problems. In the COVID-19 scenario, it affects the normal person which is having low immunity power and not properly maintained the social distance from the affected persons [1]. COVID-19 created a pandemic situation in all countries of the world and monitoring the individual persons which are not affected by this dangerous virus in the early stage is a challenging one. After pandemic life, it would be slightly easy to monitor the person by keep track of their movements regularly. But in this early stage, it is not possible to track all the human movements and stored them in a commonplace regularly [2]. An IoT-based framework is used to maintain the above-said problem with the help of the sensors which are accessed the human body actions, and the results will incorporate into the framework for the decision-making process. Not all types of sensors are allowed to directly connect with the human body; it may lead to side effects in the body. Limited frequency and functioned sensors are used directly with the human body to generate data from human actions [3]. These will take it as parameters and considered the affected person factors are generated as digital data for storing and analytic purposes. Based on the results given by the analytics from the cloud server, treatments and precautions will be suggested to the non-affected persons [4]. Moreover, the zone-level persona is identified and insisted them to strictly follow the rules for the COVID-19 virus. All over the world, a huge number of peoples is affected COVID-19 virus and it will be spread to the other people elastically within a short-range [5]. All countries are affected by this virus and innovative ideas would be suggested from the scientists along with doctor's society. Figure 1 show the peoples are affected by COVID-19 virus analysis.

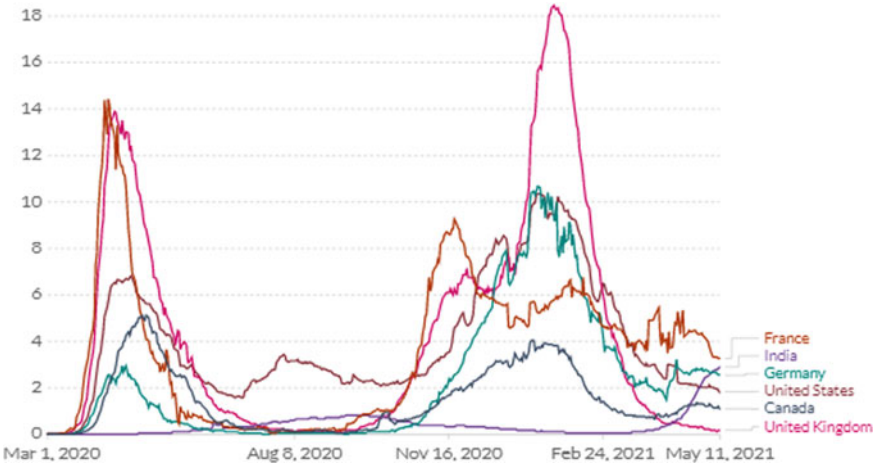

Fig. 1 COVID-19 cases in different countries

2 Related Works

COVID-19 virus research work has been carried out by all the countries in the world since 2020 onwards but the rate of spread and death is not controlled globally. Several innovative ideas revealed from scientists that vaccine is the solution to avoid spreading of the virus but experimentally it would take time to complete the process [6]. Until that, some precautionary methods and actions would have carried out by the peoples in and around the world. Some of the countries found a method to tracking the person's activities in the different sessions and insist they take precautionary actions against corona [7]. Few countries tried to prepare vaccines from natural resources and advised the people to take heavy nutrition foods. A few countries did innovative ideas to track the post-pandemic people's life for avoiding the spread of the virus to their neighbors [8]. Developing countries are worked on a data management framework for storing all kinds of data generated by the peoples in their countries. But the challenges in that work have to manage them with proper techniques and control through a centralized server [9]. The algorithms and protocols used to do that work have been carried out with recent trends like machine learning, deep learning, and IoT.

IoT is a framework used to get the data from the human body's actions and monitoring the continuous activities of them with the help of sensors. Sensors are used directly or indirectly on the human bodies and worked analytics process based on the programming written on that for processing. Notifications will be sent to the person's home or hospital for making immediate treatment to them in a quick manner [10–12]. All details are stored in a cloud server for future analytics and give a detailed report to the society about how this virus will affect and which area, zone, etc. To analyze the vigorousness of the COVID-19 virus, countries have studied various

methodologies to provide the solutions but unfortunately, time consumption is very high. They keep trying to manage the world people's data in whole or country wise or day wise with a cloud server which always researching analytics part. Zonal levels are identified in every country namely normal, affected, and heavily affected [4, 13, 14]. They framed rules and precautions for the zones separately to quarantine them easily in their living areas. Finally, there is two living life scenario such as pre-pandemic and post-pandemic which provides the overall view/ idea about the harmful crucial virus effects [15]. In this pandemic period, all the peoples of the countries should strictly follow the precautions said by the scientists and doctors then avoid unwanted gathering in crowded places [16]. COVID-19 virus would create a vital impact on people's day-to-day life and practiced them to live a healthy life by following the proper precautions and treatments.

3 Proposed Framework Architecture

The proposed architecture contains sensors on the IoT framework such as temperature, blood pressure, blood oxygen saturation, and ECG. All the sensors are combined as a mobile holding device unit or a wristwatch model for easy wearing in the human body. The power will be given to the entire circuit by either a chargeable unit or batteries. An Arduino microcontroller is used to control all the sensors, and connectivity establishment has done with Bluetooth or Wi-Fi module inbuilt on that. GSM and GPS modules are attached to this circuit for sending notifications as a location and alert messages to the users. All data generated from human bodies are stored in a local software database and then sent to the cloud server for analytics. Cloud databases are used to produce the threshold values of all symptoms of COVID-19 such as fever, oxygen level, heartbeat level, and blood pressure also. Based on these values, a person who is roaming a lot of places can self-tested with wearable device support and sent notifications to their home. The number of devices is connected to a body will not affect human nature because all are wearable and low-frequency used sensors. Since it is wearable, it can be carried everywhere with protected mode. Figure 2 explains the proposed architecture and its components.

There are several sensor units used in this proposed system and will give exact values from the human bodies for analytics purpose. Table 1 denotes the equipment used in this proposed system and their technical specifications along with justifications.

3.1 Cloud Data Repository

The cloud data base repository has been created with Amazon EC2 tools with minimum space required to collect the information from the wearable devices on spot. Connectivity between the device and cloud was made using Wi-Fi module, and

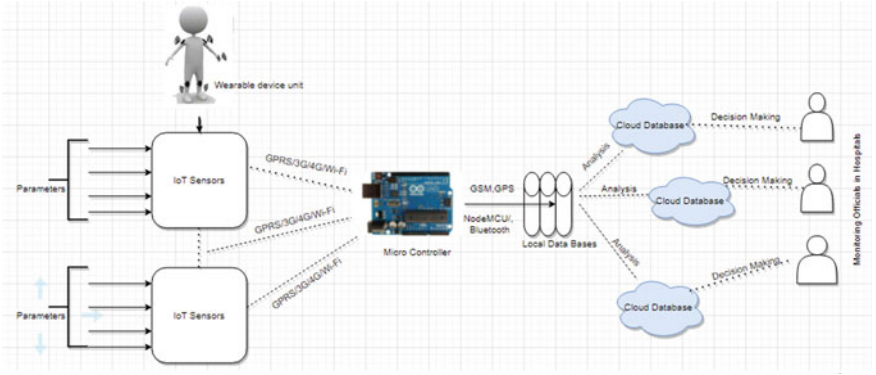

Fig. 2 Proposed architecture

Table 1 Units description used in proposed system

S. No.	Equipment	Details	Justification
1	Arduino	ATmega2560 microcontroller	To control the entire system
2	Temperature sensor	CJMCU-4466 MAX4466	To detect the temperature
3	Mobile Holder	–	To detect the presence of mobile
4	Nodemcu Module	ESB 8266	Sends messages using IOT
5	GPS Module	NEO6M	For location details tracking
6	Bluetooth module	12 V	To control the car ignition switch
7	GSM module	SIM900A	To send an alert message
8	ECG Sensor	ad8232-ecg-sensor	Take heart beat values
9	Blood Pressure sensor	BMP180 Barometric Pressure Sensor	To find the pressure level
10	Blood Oxygen saturation Sensor	Contac CMS50DL	To find the oxygen level

the decision has been made after the analytics part done at data centers of cloud repository. The cloud analytics part has done using machine learning techniques in order to identify the symptoms specified in the training data sets already stored. Based on the threshold value set in the repository trained data, the result will give the decisions about patient's health. Machine learning techniques are used to predict the COVID-19-affected persons from the trained data sets which are already collected and stored in a data repository for analytics. Multiple factors and parameters are taken for decision-making about the patients' health condition periodically collected from different places and persons through the IT wearable devices.

Monitoring officials are available in the hospitals and the places where these devices are using. Their responsibilities are identifying the most affected persons from the different done and contact them using their GPS locations during analytics period. GSM unit is used to send the notifications to these officials about those who are affected by COVID-19 virus. The collection of data has matched with the previous data stored as training data in the repository was done by ML techniques used in Cloud repository. The data model is refined by the deep learning techniques periodically to avoid the conflicts from the device data. A dashboard is used in local database maintain software, and it shows all the detailed analytics and classification about the affected person details.

3.2 Prediction of Cases Analysis

Total of 150 samples are stored in a repository as a training set, and the inputs generated from various persons on different locations can be captured then compared with these sample training sets with threshold values. It is also called as instances that are stored in a repository to make decisions about the patients' health condition immediately. Machine learning algorithms are used to predict the symptoms and their matched threshold values through the wearable devices. That part will be explained in experimental section with their threshold values. Simulation of all the values is collected from device and matched with the already stored data in the cloud repository.

3.3 Assessment Based on Performance

Assessment can be done by the factors called root mean square error, Receiver Operational Characteristics (ROC) area, accuracy, and the estimated time. For computing the data, cross validation and uncertainty matrix are the techniques used in the cloud repository.

3.3.1 Confusion Matrix Representation

A 2 * 2 matrix can be created with computed class and real class as a row and column for validation. Four possibilities as values considered for calculation.

- Positive True Value (PT)
- Positive False Value (PF)

- Negative False Value (NF)
- Negative True Value (NT)

PT has declared as appositive values and mentioned as positive in a design model then PF has decided as negative but it has labeled as positive instances initially. NF can be denoted as negative values instances that are defined positives, and NT has declared as both negative instances.

3.3.2 Calculation of Cross-Validation

It is a mathematical approach used to classify the efficiency of learning from the inputs in the repository as instances. One instance can be used and it will be broken into 10 instances for verification but each instance is doing 15 times iterations for getting accurate result. Every time, the same method can be executed in both computed class and real class members and output is taken for analytics for the decision-making purpose.

Accuracy of the each iteration about the instances is calculated by the Eq. 1 where all the values are taken from the different instances.

$$\text{Accuracy} = \frac{\text{PT} + \text{NT}}{\text{PT} + \text{NT} + \text{PF} + \text{NF}} \tag{1}$$

Root Mean Square Error (RMSE) can be calculated with the average values of all instances considered from the iterations. That value will be calculated with Eq. 2.

$$\text{RMSE} = \frac{\sqrt{\text{PF} + \text{NF}}}{\sqrt{\text{PT} + \text{NT} + \text{PF} + \text{NF}}} \tag{2}$$

Receiver Operational Characteristics (ROC) can be calculated using the classifiers that are used for matching the instances calculated in the matrix. The classifier accuracy was calculated against the positive false rate and the positive true rate. It can express by Formulas 3 and 4.

$$\text{Positive True} = \frac{\text{PT}}{\text{PT} + \text{NF}} \tag{3}$$

and

$$\text{Positive False Rate} = \frac{\text{PF}}{\text{PF} + \text{NT}} \tag{4}$$

4 Work Flow

This system is entirely used to predict the early stage COVID-19 virus-affected persons in their living areas based on the symptoms declared with threshold values of all. A person traveling from one place to another place wearing the IoT framework model device, that person's BP, heartbeat, oxygen level, and temperature levels are measured by the sensors inbuilt in this device. Then, it is stored and accessed by the local software installed on this device. If it matches the already fixed threshold value, then the person should not go anywhere and they will be considered as an affected person. If not their details will be stored in the database for further processing, they have to use sanitizer and wearing masks continuously to avoid spread from others. If the person traveling to a long distance and not maintained the precautions suggested by this system, then the oxygen and temperature level of that person will be decreased in various zones. The location details are tracked by the GPS and if they will affect, then the notification will be sent to the hospital or home immediately. The important instruction given to the persons is to keep wearing a mask, sanitizing their hands frequently, and maintain social distancing between the peoples in crowded places. Figure 3 summarizes the work flow of the entire proposed system in a detailed manner.

5 Experimental on Zone Level Setup

The experimental setup is taken with several persons wearing the devices and asks them to travel to different places for tracking. Normally, a person wearing a mask and sanitizing their hands frequently will never affect. But if they are not maintaining social distance, then the affected level is increased. Based on this, the zones are classified into three levels namely normal zone, affected zone, and heavily affected zones. The last zone is a danger zone, and in that, all the peoples are affected be in quarantine. The personal details are stored in a local database which is installed on inbuilt software for threshold level checking and sent to the cloud server for further analytics. The distance between the peoples is 6 m range will not be affected whereas less than 3 m will be in the affected zone. This will give notification to the hospitals about the person's affected rate, and it will be helpful for them to take immediate treatment. Figure 4 describes the detailed view of zone levels.

Various symptoms have collected from the persons on their zones, and it will be calculated immediately with the local software database and given a detailed treatment procedure or pre cautionary tips to the persons on that spot. Tables 2 and 3 [17–19] summarize the symptoms and its threshold levels for the COVID-19 patient's gender wise.

From the above tables, the affected rate of COVID-19 in different zones resembles a bad impact on male peoples heavily due to roaming and not maintaining the precautionary systems. Female persons are affected low in these zones due to the healthy

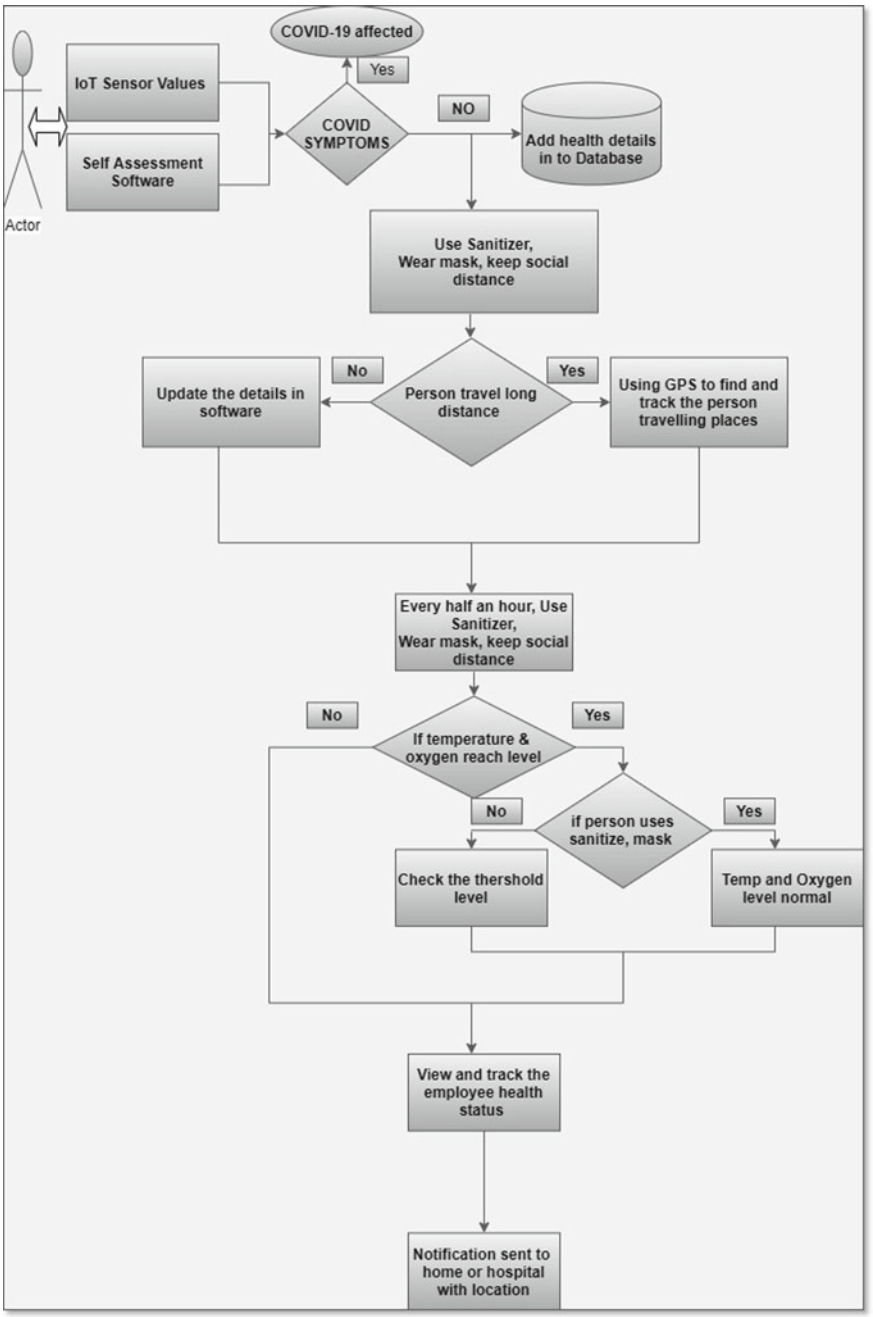

Fig. 3 Work flow of proposed architecture

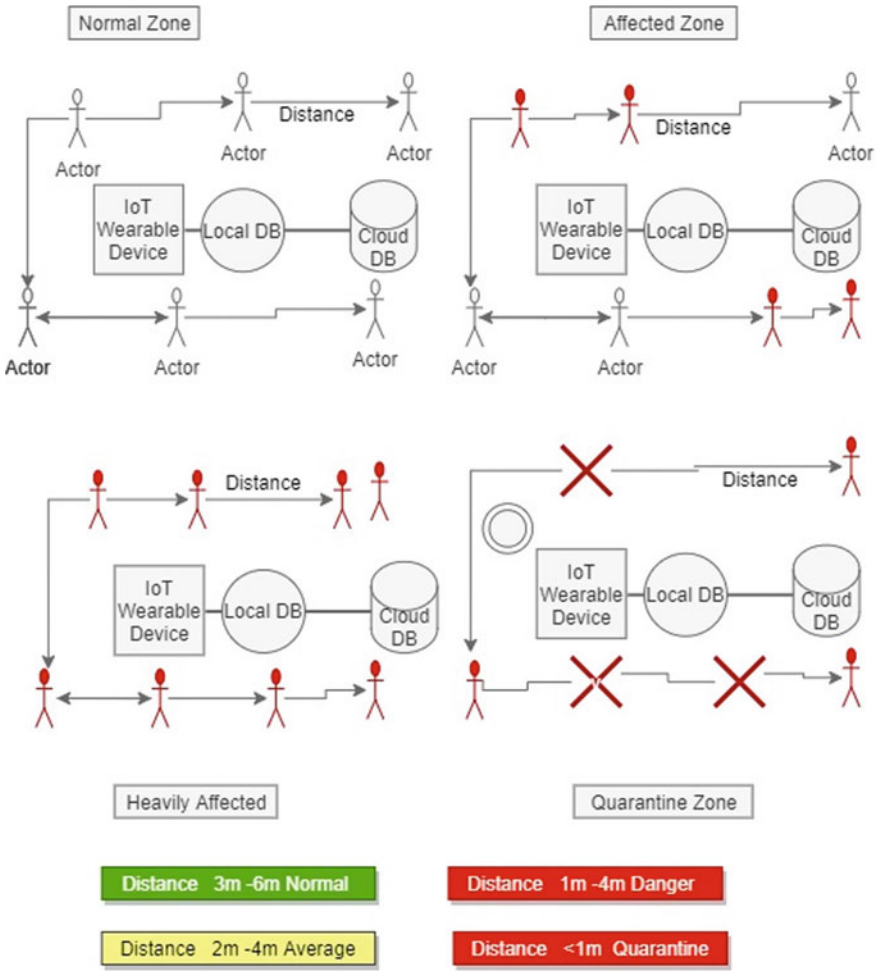

Fig. 4 Zone level person tracking system

foods for increasing immunity powers. We have not considering this test for children and aged persons because the sensors available in wearable devices directly dealing with bodies may cause some side effects. We would like to give suggestions to the peoples that they are not coming out of the home regularly if they come wearing a mask, sanitizing hand, and maintaining social distances are the primary precautions taken for avoiding the spread of viruses. The threshold level varies for children and aged peoples but the precautionary procedures are common for all aged peoples in a country.

Table 2 Symptoms threshold levels for male

Description	Non-COVID	COVID	Threshold level	Affected rate	Actions taken if threshold level reached
Gender of the person	Male	Male	–	High	Avoid roaming
Age of the person	18–45	18–45	$> 18 < = 45$	High	Take care of Stress, Sugar, BP
Temperature level	92–98.6 F	>100 F	98.6–99.6 F	High	Take test for COVID-19
Saturation level of oxygen	95–100	<90	94	High	To be hospitalized
Number of beats	72–76	70–78	<70	High	High BP, and to be hospitalized
Pulse rate level	72–80	90–120	60–80	High	Need oxygen
Cough level (5 s)	2–3	7–12	>8	High	Take treatment
Blood Pressure	120/80	150/95	130/85	High	To be hospitalized

Table 3 Symptoms threshold levels for female

Description	Non-COVID	COVID	Threshold level	Affected rate	Reason for affected/Not affected
Gender of the person	Female	Female	–	Low	Improve immunity power
Age of the person	18–45	18–45	$>18 < = 45$	High	Take care of Stress, Sugar, BP
Temperature level	92–98.6 F	>100 F	98.6–99.6 F	High	Take test for COVID-19
Saturation level of oxygen %	95–100	<90	94	High	To be hospitalized
Number of beats	72–76	70–78	<70	High	High BP, and to be hospitalized
Breathing shortness (Blood Pressure)	72–80	90–120	60–80	High	Need oxygen
Cough level (5 s)	2–3	7–12	>8	High	Take treatment
Blood Pressure	120/80	150/95	130/85	High	To be hospitalized

6 Results and Discussions

The experimental setup results taken from the different zones are visualized using modern tools and based on those precautionary methods will be suggested to the affected peoples. One month of data has taken from the person datewise, where they have gone, and how long they have traveled all are tracked with the help of GPS systems and will be stored in a database locally with customized software. Finally, the analytics made like how many cases are active, positive, cured, and death from these results. Since the data has been taken in real time we cannot predict it at the time itself. We have to do analytics then only it is possible to find the solutions. On time, it may measure the threshold level of all symptoms values and informed the hospitals if they crossed.

6.1 Calculation of Confusion Matrix

The values taken from the 10 instances with 10 classifiers in one iteration can be calculated and put it in matrix of 2 * 2 format. Positive values are represented higher values, and it is represented in upper-left and lower-right boxes. Low values are represented in lower-left and upper-height boxes for easy identification. Figure 5 denotes all.

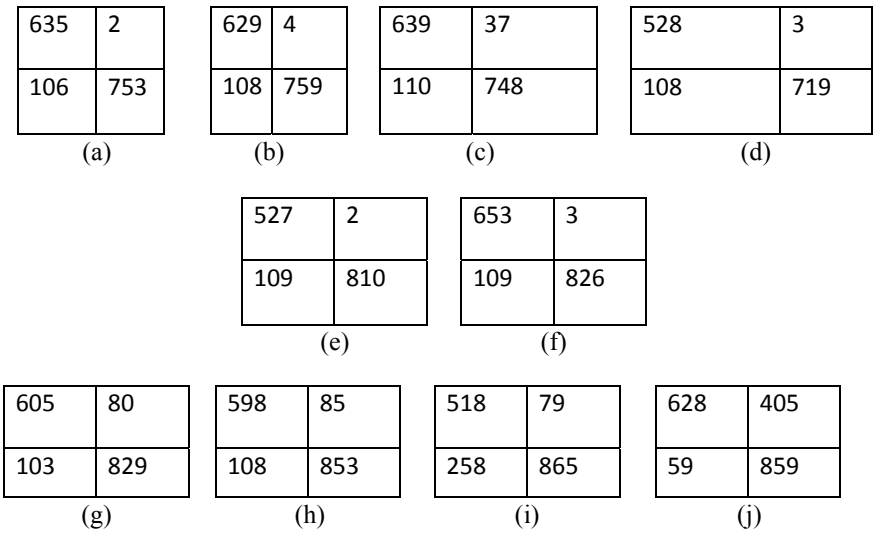

Fig. 5 **a**–**j** Confusion matrix values for different instances

6.2 Performance Measurement Value

Every value is measured from the 10 classifiers and 10 instances through the cloud repository values, and it is performing the cross validation function with the samples. Each are given the values of RMSE, ROC fields as curve, and their accuracy levels tested by various popular algorithms known as SVM, Naïve Bayes, Neural Network, K-Nearest Neighbor, and Decision table algorithms with our new approach. Out suggested IoT-based system is compared with all these algorithms, and results were noted as curve in Fig. 6a–f.

The above figures represent the ROC curves for the classifiers used in different techniques like SVM, Neural Network, Naïve Bayes, KNN, DNN, and decision table with the new approach IoT wearable device system. Figure 6a–f denotes the difference of the ROC when the positive false rate and positive true rate calculated form the IoT framework and stored in a cloud repository. In each figure, the new approach used by IoT framework has given more positive rates for identifying the right person who has affected the COVID-19 virus using confusion matrix. The normal symptoms and high level symptoms can be classified in every technique, so that the decision-making system is very quick when compared with the previous techniques. Here, machine learning techniques are used to check the modifications in the input data whereas pre-defined training data sets are compared with new data.

Figure 7 describes the performance measures of the entire system build with IoT. There are lot of criteria taken for consideration but the factors such as accuracy, RMSE, and ROC was considered. More or less all the techniques are given the nearest values of the accuracy but the new approach has given more due to the IoT system designed for handling that positions. The other factors like RMSE have given poor values initially but later new trends had come and their capacity has increased in performance. Similarly ROC value has been compared with all old techniques with our new system, for getting better results from the IoT environment devices.

7 Conclusion

The COVID-19 virus spread can be avoided by taking precautionary methods suggested by the scientist but maintained the procedures continuously is a challenging task for all the peoples. Moreover, suggestions are given to a common society of peoples for fighting against pandemic life. This research article provides the methodology to maintain the data which are generated by the human bodies of normal peoples and taken for analytics purposes with the threshold values defined by the standards. When tracking of persons' day-to-day life is monitored regularly, it will be doing good social impact on the peoples who are aware of this pandemic situation. This work implemented the patient's parameters of affected factors and keeps monitoring to avoid the effects. A lot of new innovative methods have come

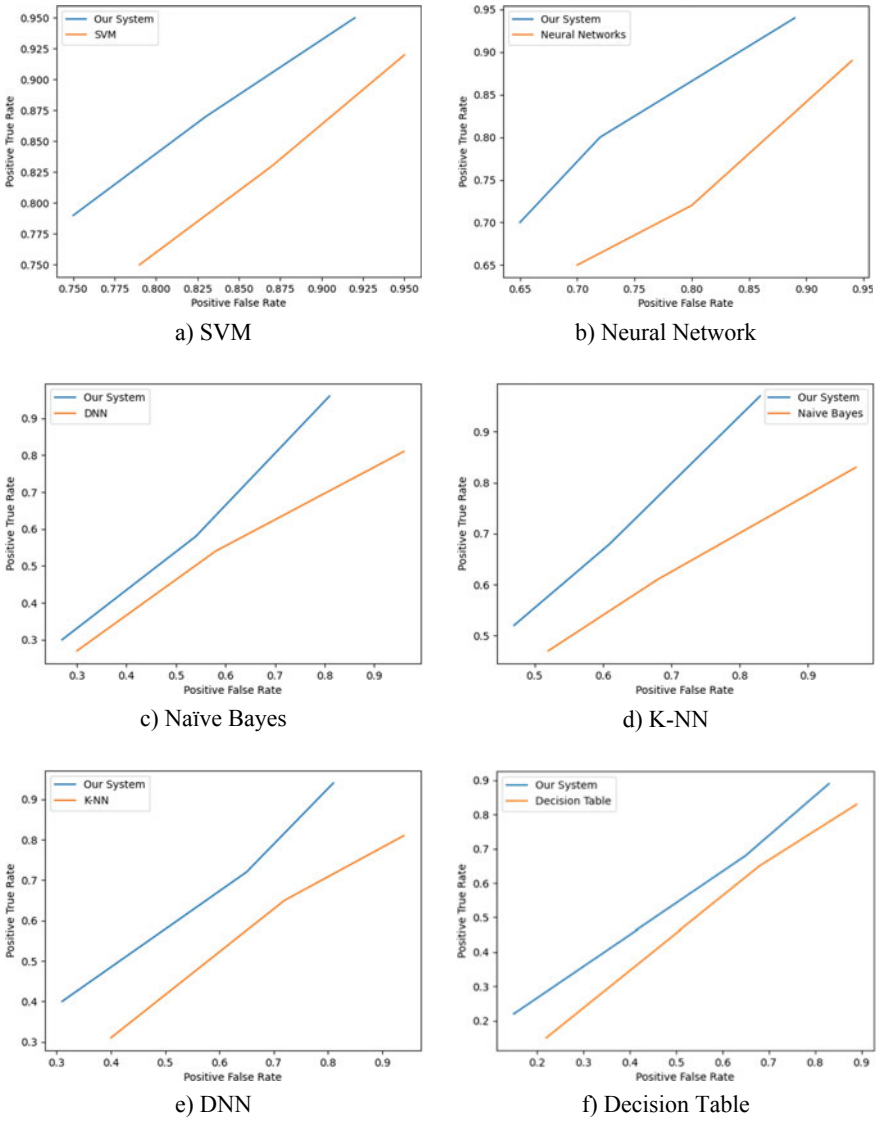

Fig. 6 **a–f** ROC comparison

across this pandemic situation but this method provides a better to detect early prediction of COVID-19 with IoT wearable devices. It will give a cost-effective system and carried to all places easily. Maintenance of this device is easy to handle, and power to this system is either rechargeable or battery backup generally. This system provides effective data management framework in IoT during this pre-pandemic life. This system categorized the affected people's day-to-day actions and advised them not to

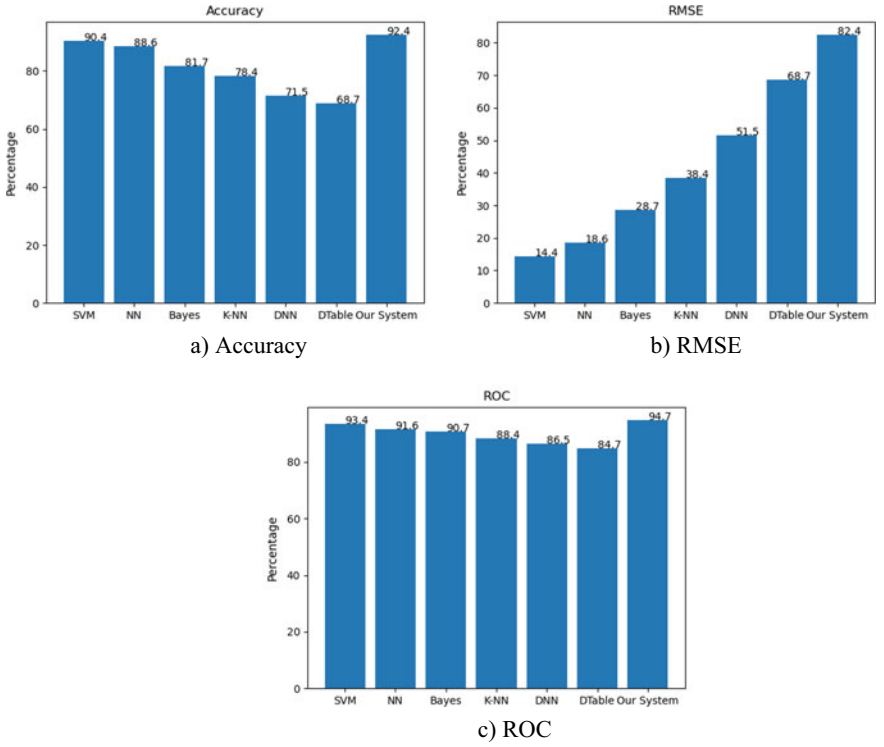

Fig. 7 **a–c** Performance measures

enter into various zones often. The entire system has given the high rate of detection of virus-affected persons and response to the users very less time. Notifications are sent to a limited number of persons with the location details immediately.

8 Future Enhancement

The proposed system in this research work is handled only with limited data since the person is traveling to limited areas and distances. In the future, this system will be working on longer distances and a huge volume of data generated by a single person. Moreover, this system is not advisable for children and aged persons due to the number of sensors used in wearable devices. Next level, we have to plan and design for them also to easily wear this device. Generally monitoring and controlling used in this system by GPS, GSM modules attached the device. The future device consists of several more sensors to predict the disease in early stage not only the COVID-19 virus. The notifications sent by this system are limited in the number of peoples responding. In the future, we have to increase more number of persons to contact, especially the

nearest persons who will come and give first aid immediately to avoid the delay. This application-oriented research work is further carried out for blind people also to include various cloud storage modules [20, 21] used for their convenience. Modern tools are used to visualize the predicted data from wearable devices and write suitable algorithms to extract the information from them with high speed and accurate values. The bid data analytics technique device will be implemented in this and used for all kinds of peoples managed data using IoT framework effectively [22].

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