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A Framework for Detection and Monitoring of COVID-19 using IoT Environment in Pre-Pandemic Life

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Abstract: COVID-19 (SARS-Cov-2virus), a family of CORONA viruses, is disseminated worldwide to make a pandemic to the whole world thereby disturbing human being's normal life. As per World Health Organization (WHO) statement, it spreads consistently and affects human society unless they follow the precautionary measures prescribed by them. Moreover, this virus disseminated from the human-to-human body within a short period which even leads to death. Intense Research is carried out globally to produce vaccines for the virus. Meanwhile, people are advised to protect themselves through various operational procedures and precautions that are prescribed periodically. Recent techniques are used to detect the COVID-19 virus symptoms in the early stage of normal people and are insisted to take precautionary steps in early pandemic life. IoT is a framework used in the human body with wearable devices developed using sensors to communicate directly or indirectly with human bodies. Sensors generate signals from the human body and send them to the server connected via the internet. Data analytics are done on the server-side to diagnose whether the human is affected by the COVID-19 virus or not. Finally, data is stored in a real-time cloud server which is managed as a framework efficiently. This research work proposes a framework for data management for early detection and monitoring of the COVID-19 virus-affected people in the early stage through IoT wearable devices in a pre-pandemic life. A pre-trained model was created with Deep Neural Networks (DNN) in order to make predictions based on the data from the human bodies using classifiers. Experiments are conducted at different conditional zones and their results are shown as symptoms of COVID-19 with localized datasets. Parallel work reveals that data management in a cloud server by tracking and storing the data. This research work data set is derived from various internet sources like government websites, and the Kaggle platform(Open Research Dataset about COVID-19), and the results have exposed the diagnosis or detection of COVID-19 precisely in real-time.

Keywords: COVID-19, Vaccines, Pre-pandemic, Cloud server, Data Management, Wearable Devices

1. INTRODUCTION

COVID-19 virus affects the normal life of humans all over the world. In this digital era, new techniques and innovative ideas are used for detection still, early detection or assessment of disease is a challenge due to the lack of real-world application problems. In the COVID-19 scenario, it affects the normal person with very low immunity who fails to maintain the social distance properly from the affected persons [1]. COVID-19 created a pandemic situation in all countries of the world and thus monitoring an individual person who is not affected by this dangerous virus in the early stage is a challenging task. After a pandemic life or Lockdown, it becomes slightly easy to monitor the person by keeping track of their movements regularly. But in the early stage, it is not possible to track all the human movements and store them in a commonplace regularly [2]. An IoT-based framework is used to address the above-said problem with the help of sensors that access the human body's actions and the results get incorporated 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 for the body. Sensors with limited frequency and function are used directly by the human body to generate data from human actions [3]. These sensors use the parameters which are extracted from an affected person and the parameters are generated as digital data for storing and analytical purposes. Based on the results given by the analytics from the cloud server treatments and precautions are suggested for the non-affected persons [4]. Moreover, the zone-level persona is identified and insisted on strictly following the rules for the COVID-19 virus. All over the world, a huge number of people are affected by the COVID-19 virus and it spreads to other people drastically within a short-range [5]. Almost all countries

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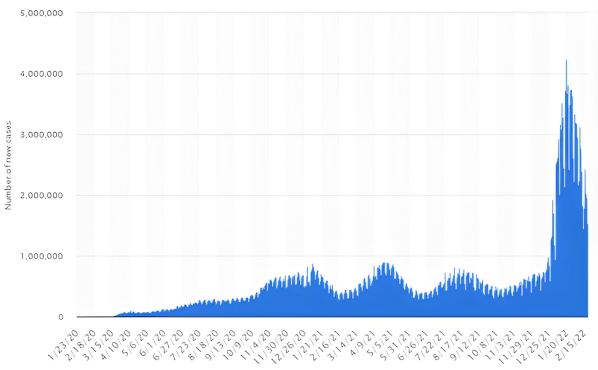

Figure 1. COVID-19 cases in different countries

around the globe are affected by this virus and innovative ideas and suggestions are expected from experts, scientists, and doctors. The following Figure 1 provides the effect of COVID-19 across different countries.

2. RELATED WORKS

COVID-19 virus research work is carried out by all the countries in the world from 2020 onwards but the rate of spread and death is not controlled globally. After applying several innovative ideas, scientists conclude that the vaccine is the solution to avoid the spreading of the virus. But practically it takes more time to complete the process [6]. Until that time the world is left with no other option other than following some precautionary methods and actions. Some of the countries found a method to track 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 people to take nutritious foods. A few countries followed innovative ideas to track the post-pandemic people's life for avoiding the spread of the virus to their neighbors [8]. Developing countries work on a data management framework for storing all kinds of data generated by the people in their countries. But the challenge in that work is to manage them with proper techniques and control through a centralized server [9]. The algorithms and protocols used to do that work are carried out with recent trends like machine learning, deep learning, and IoT. IoT is a framework used to get data from the human body's actions and monitor their continuous activities with the help of sensors. Sensors are used directly or indirectly on the human body and programs are written to perform analytics on the data collected from sensors. Notifications are sent to the person's home or hospital to treat the person immediately [10] [11] [12]. All details are stored in a cloud server for future analytics and give a detailed report to the society about how this virus affects and which area, zone, etc. To analyze the vigorousness of the COVID-19 virus countries have studied various methodologies to provide solutions but unfortunately, time consumption is very high. The people's data are stored in cloud servers say day-wise, country-wise, or as a whole which is used for research and analytics to try for a solution. Zonal levels are identified in every country namely normal, affected, and heavily affected [13] [14] [15]. They framed rules and precautions specific to that zone 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 [16]. During this pandemic period, all the people of the countries should strictly follow the precautions said by the scientists and doctors and also avoid unwanted gatherings in crowded places [17]. COVID-19 virus creates a vital impact on people's day-to-day life and practices them to live healthy life by following the proper precautions and treatments. Dataset of 14251 from Open Research Dataset about COVID-19 has taken for reference to refer where they went, and how long they traveled all are tracked with the help of GPS systems and then stored in a database with WEKA software [18]. The pre-trained neural model is used to predict the weights of each layer such as input, hidden, pooling, soft-max, and output layer. The features extracted values are stored in a stack for verification and in the future process, it will be accessed from this trained data stored on the stack. Representation learning [19] is the concept of using features of the images to put in the hidden layer when it is working online for the betterment of the results. Finally, user feedback is taken for the final output which is exactly connected to this learning.

3. PROPOSED 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 device or a wristwatch model for a human to wear with ease. The entire unit is powered with either a chargeable unit or batteries. An Arduino microcontroller is used to control all the sensors and connectivity is established wirelessly with Bluetooth or Wi-Fi module inbuilt in that. GSM and GPS modules are attached to this circuit to send location data 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 such values a person traveling or roaming around places can be self-tested with the help of wearable device support and notifications are sent to their home immediately. The devices connected to the body will not affect human nature as all are wearable and low-frequency sensors. Since it is wearable it can be carried everywhere in a protected mode. Figure 2 explains the proposed architecture and its components.

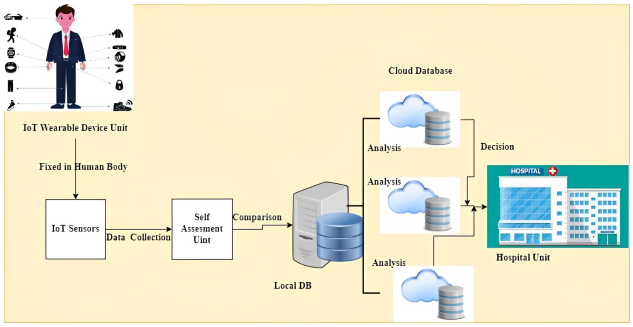

Figure 2. Proposed Architecture

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

A. *Cloud Data Repository*

The cloud database repository is 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 is achieved through a Wi-Fi module and the decision is made based on the analytics part performed at data centers of the cloud repository. The cloud analytics part is 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 gives the decisions about the 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 using data periodically collected from different places and persons through the IT wearable devices. Monitoring person is available in the hospitals and places where these devices are installed. Their responsibilities include identifying the most affected people from different zones and contacting them using their GPS locations during the analytics period. GSM unit is used to send notifications to the personnel about the COVID-19-affected people. The data match between the collected data and the stored data is carried out using ML Techniques in the Cloud repository. The data model is defined by the Deep Learning techniques periodically to avoid conflicts with the device data. A dashboard is used in local database maintenance software to show all the detailed analytics and classification of the affected person.

B. *Pre-Trained Model using DNN*

Dataset of 14251 from Open Research Dataset about COVID-19 has taken for reference and local data for one month is taken from the local persons date-wise like where they went, and how long they traveled all are tracked with the help of GPS systems and then stored in a database locally with WEKA software. This framework is dedicated to signs like the history of travel by affected peoples to apprehensive areas, and communication history with possibly diseased people. Few machine learning algorithms are used like Support Vector Machine, K-Nearest Neighbor, Naïve Bayes, Decision Table, and neural networks are used. In this approach, we used Deep Neural Network pre-trained model with classifiers. Various classifiers are predicted the most affected person in the danger zone area based on the confusion matrix from the KNN algorithm result and the pre-trained model classifiers. Out of 10000 sets of COVID-19 set of records, almost 1500 records were identified as the most affected zone and 900 records were in the danger zone from the data sets. The size of the dataset is taken from the localized person is less than 1024MB

C. *Assessment based on Performance*

Assessment is done by Root Mean Square Error, Receiver Operational Characteristics (ROC) area, accuracy, and the estimated time. For computing, the data cross-validation and uncertainty matrix are used in the cloud repository.

D. *Confusion Matrix Representation*

Machine learning algorithm helps in prediction using Confusion Matrix. A 2*2 matrix is created with computed class and real class as a row and column for validation. Four possibilities are considered as values for calculation.

- True Positive (TP)
- False Positive (FP)
- False Negative (FN)
- True Negative (TN)

TP is the predicted value that matches the actual value and the actual value is positive. TN actual value is negative and the model predicted a negative value. FP is the false predicted value which is negative but the model predicted a positive value. It is also called type 1 error. FN is a negative value but predicted false and is called a type 2 error. Figure 3 denotes the details.

TABLE I. Units description used in the proposed system

Equipment	Details	Justification
Arduino	ATmega2560 microcontroller	To control the entire system.
Temperature sensor	CJMCU-4466 MAX4466	To detect the temperature.
Nodemcu Module	ESB 8266	Access Wi-Fi
GPS Module	NEO6M	For location details tracking
GSM module	SIM900A	To send an alert message
ECG Sensor	ad8232-ECG-sensor	Take heartbeat values
Blood Pressure sensor	BMP180 Barometric Pressure Sensor	To find the pressure level.
Blood Oxygen saturation Sensor	Contact CMS50DL	To find the oxygen level.

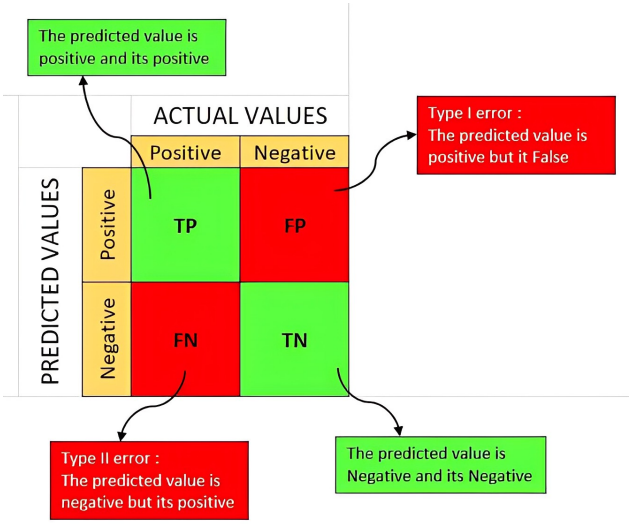

Figure 3. Confusion Matrix Representation

E. Calculation of Cross-Validation

It is a mathematical approach used to classify the efficiency of learning from the inputs in the repository as an instance. A single instance is broken into multiple instances which undergo numerous iterations to achieve an accurate result. Every time the same method is executed in both computed class and real class members and output is taken for analytics for the decision-making purpose. The accuracy of each iteration about the instances is calculated by Equation 1 where all the values are taken from different instances.

$$Accuracy = TP + TN/TP + TN + FP + FN \quad (1)$$

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

$$RMSE = \sqrt{FP + FN}/\sqrt{TP + TN} * 1/\sqrt{FP + FN} \quad (2)$$

Receiver Operational Characteristics (ROC) is calculated using the classifiers that are used for matching the instances calculated in the matrix. The classifier accuracy is calculated against the positive false rate and the positive true rate. It is expressed by the following formulas 3, 4.

$$PositiveTrue = TP/TP + FN \quad (3)$$

$$PositiveFalseRate = FP/FP + TN \quad (4)$$

4. WORK FLOW

The entire system is 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 wears the IoT framework model device during his travel everywhere. That person's BP, heartbeat, oxygen level, and temperature levels are measured by the sensors inbuilt in this device. Then the data is stored and accessed by the local software installed on this device. If it matches the fixed threshold value then the person is stopped from traveling anywhere as he is diagnosed as an affected person else their details are stored in the database for further processing. They are instructed to use sanitizer periodically and wear masks mandatorily to avoid spread from others. If the person travels a long distance without maintaining the precautions suggested by this system, then the oxygen, and temperature level of that person is decreased in various zones. The location details are tracked by the GPS and if it is affected, then the notification is sent to the hospital or home immediately. The important instruction given to the people is to keep wearing a mask, sanitizing their hands frequently, and maintain social distancing between the people in crowded places. Figure 4 summarizes the workflow of the entire proposed system in a detailed manner.

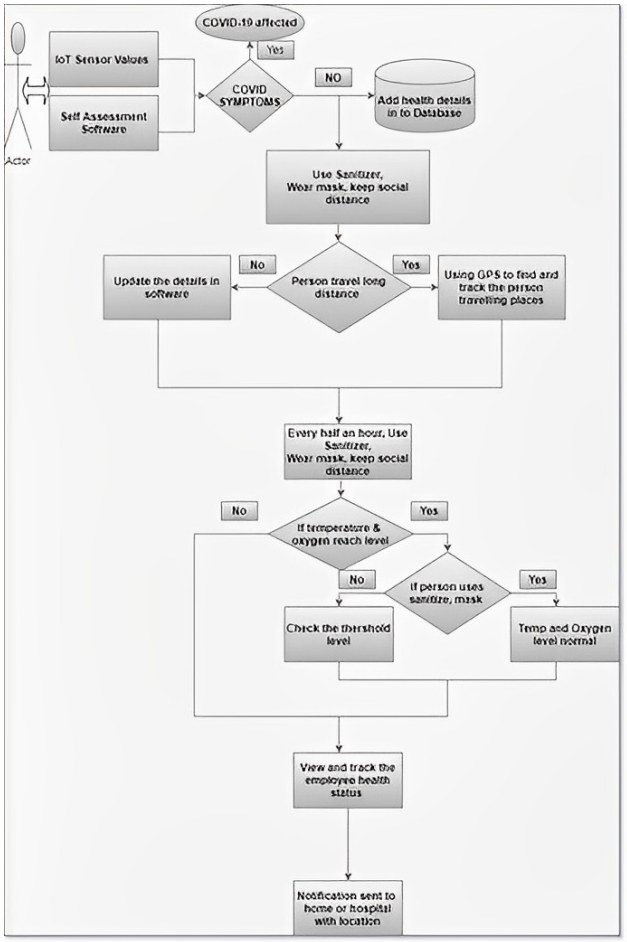

Figure 4. Work Flow of proposed architecture

5. EXPERIMENTAL ON ZONE LEVEL SETUP

The experimental setup is prepared by instructing several persons to wear the devices and asking them to travel to different places for tracking. Normally a person wearing a mask and sanitizing their hands frequently rarely gets affected. 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 people are affected and are put under 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 people in the range of 3m-6m is the normal zone. More than that gives notification to the hospitals about the person's affected rate and it helps them to take immediate treatment. Figure 5 describes the detailed view of zone levels.

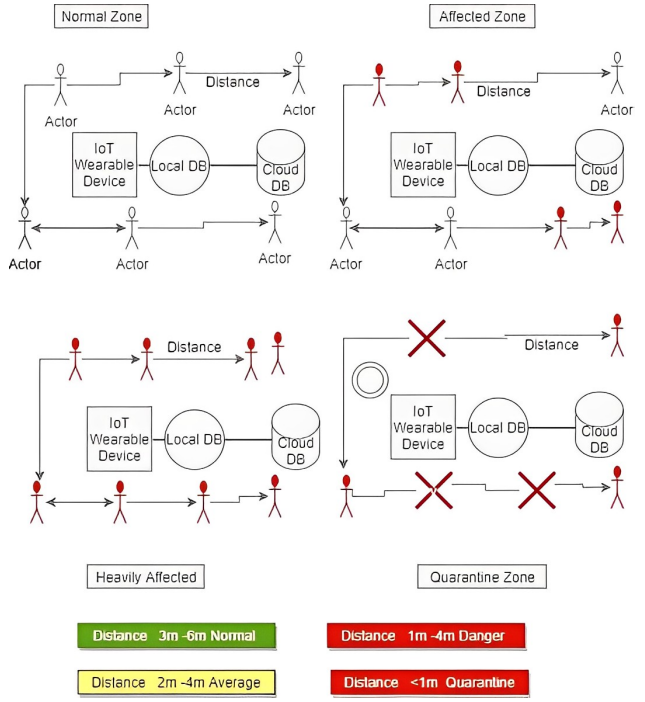

Figure 5. Zone level-person tracking system

Various symptoms are collected from the people in their zones. The data is used in the local software database to calculate and give either a detailed treatment procedure or precautionary tips to the persons on that spot immediately. Table 2 [20] [21] [22] summarize the symptoms and their threshold levels for the COVID-19 patients gender-wise.

From the tables, the affected rate of COVID-19 in different zones resembles a bad impact on male people heavily due to roaming and not maintaining the precautionary systems. Female persons are affected low in these zones because of healthy foods for increasing immunity. We do not consider this test for children and aged people as the sensors available in wearable devices directly deal with bodies may cause some side effects. The people are suggested not to come out of their house frequently. Even if they come, wearing a mask, sanitizing hands, and maintaining social distancing are the primary precautions that need to be taken for avoiding the spread of viruses. The threshold level varies for children and aged people but precautionary procedures are common for all aged people in a country.

6. RESULTS AND DISCUSSION

The experimental setup results taken from the different zones are visualized using modern tools and based on those precautionary methods suggested to the affected people. Dataset of 14251 from Open Research Dataset about COVID-19 has taken for reference and local data for one month is taken from the local persons date-wise like where they went, and how long they traveled all are tracked with

TABLE II. Symptoms and threshold levels

Description	Non-COVID/COVID	Threshold level	Reasons
Gender	Male, Female	—	Immunity
Age	18-45	Greater than 18-45	Stress
Temperature	92-98.6 F/Greater than 100F	98 .6-99.6F	Take test
Saturation of oxygen Percentage	95-100/Less than 90	94	hospitalized
Heart beats	72-76 /70-78	Less than 70	High BP
Breathing shortness (Blood Pressure)	72-80/90-120	60-80	Need Oxygen
Cough level (5 sec)	2-3/7-12	Greater than 8	Take treatment
Blood Pressure	120/80-150/95	130/85	To be hospitalized .

the help of GPS systems and then stored in a database locally with WEKA software. . The size of the dataset is taken from the localized person in less than 1024MB. This framework is dedicated to signs like the history of travel by affected peoples to apprehensive areas, and communication history with possibly diseased people. Finally, the analytics is made like how many cases are active, positive, cured, and dead from these results. Since the data is taken in real-time, prediction is not possible at the same time. The solutions arrive only after thorough analytics of the data. On-time measures the threshold level of all symptoms as values and informs the hospitals if they crossed.

A. *Calculation on Confusion Matrix*

Machine learning algorithm helps in prediction using Confusion Matrix. The values taken from the instances with the classifiers in one iteration are calculated and put in the matrix of 2*2 format. Positive values are represented as high and it is represented in upper-left and lower-right boxes. Low values are represented in lower-left and upper-right boxes for easy identification. Figure 6 denotes all the instances that occurred.

635	2
106	753

629	4
108	759

630	5
115	759

625	3
109	756

590	39
106	758

627	2
106	758

648	1
104	750

Figure 6. Confusion Matrix values for different instances (SVM, Neural Network, DNN, KNN, Naïve Bayes, Decision table, and our pre-trained system

- Scenario 1: TP 635 means 635 positive data points are predicted and classified by the model
- Scenario 2: TN 753 means 753 negative data points are predicted and classified by the model.
- Scenario 3: FP 590 means 590 negative class data points are classified incorrectly but belong to the positive model.
- Scenario 4: FN 39 means 39 positive class data points are classified incorrectly but belong to the negative model. The larger and lower values are used to take decisions on what basis the result is declared.

B. *Performance Measurement Value*

Every value is measured from the 10 classifiers and 10 instances through the cloud repository values and it performs the cross-validation function with the samples. Each is given the values of RMSE, and ROC fields as curves, and their accuracy levels are tested by various popular algorithms known as SVM, Naïve Bayes, Neural Network, K-Nearest Neighbor, and Decision table algorithms with the new approach. The suggested IoT-based system is compared with all these algorithms and the results are denoted as a curve in Figures 7-12.

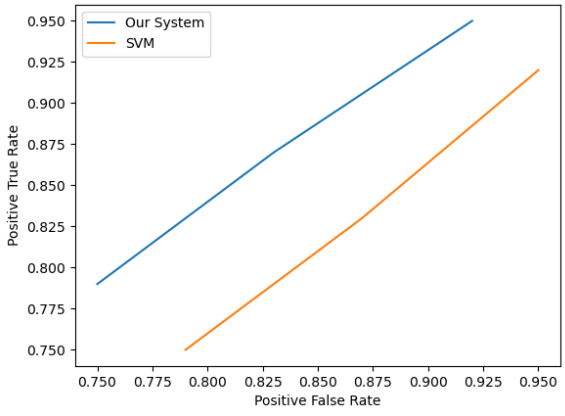

Figure 7. SVM

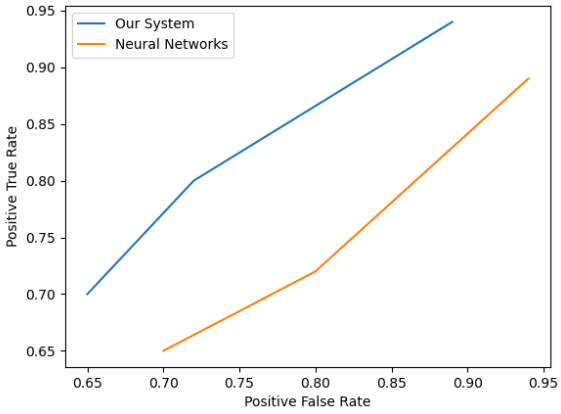

Figure 8. Neural Network

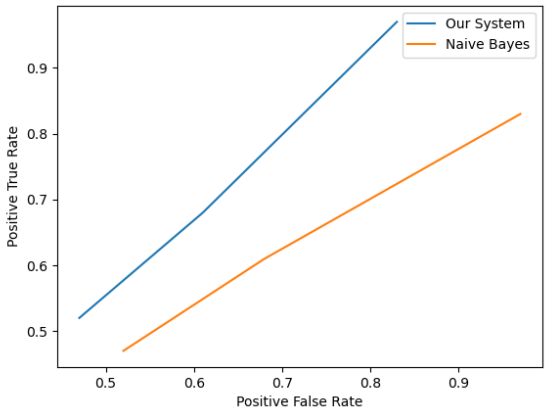

Figure 11. Naive Bayes

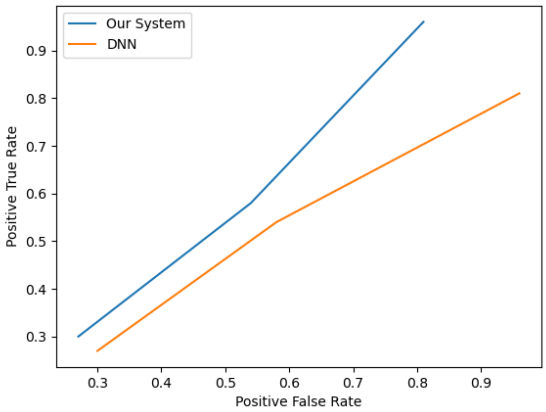

Figure 9. DNN

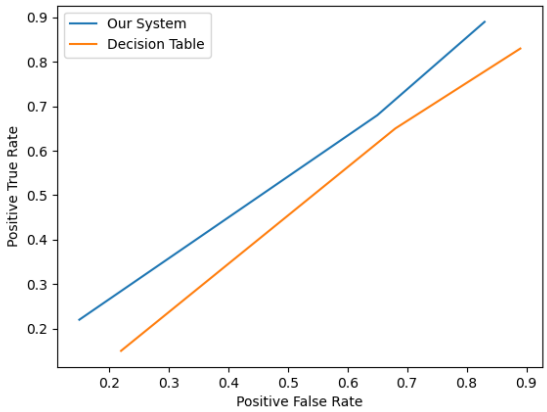

Figure 12. Decision Table

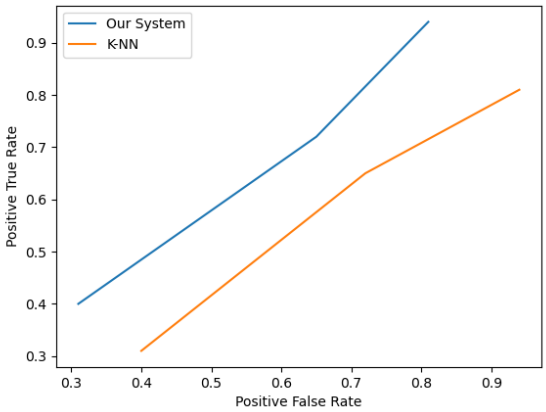

Figure 10. K-NN

The above figures represent the ROC curves for the classifiers used in different techniques like SVM, Neural Network, Naïve Bayes, K –NN, DNN, and decision table with the new approach IoT wearable device system. Figure 7-12 denotes the difference of the ROC when the positive false rate and positive true rate are calculated from the IoT framework and stored in a cloud repository. In each figure, the new approach used by the IoT framework gives more positive rates for identifying the right person who is affected by the COVID-19 virus using a confusion matrix. The normal symptoms and high-level symptoms are classified in every technique so that the decision-making system is very quick when compared to 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. Figures 13,14,15 describes the performance measures of the entire system built with IoT. There are a lot of criteria taken into consideration but the factors such as accuracy, RMSE, ROC are

considered. More or less all the techniques give the nearest value of the accuracy but the new approach gives more due to the IoT system designed for handling that positions. The other factors like RMSE give poor values initially but later new trends come and their capacity increases in performance. Similarly, the ROC value is compared with all old techniques with our new system, for getting better results from the IoT environment devices.

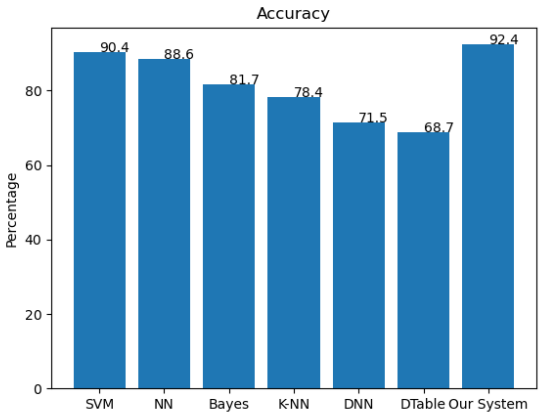

Figure 13. Accuracy

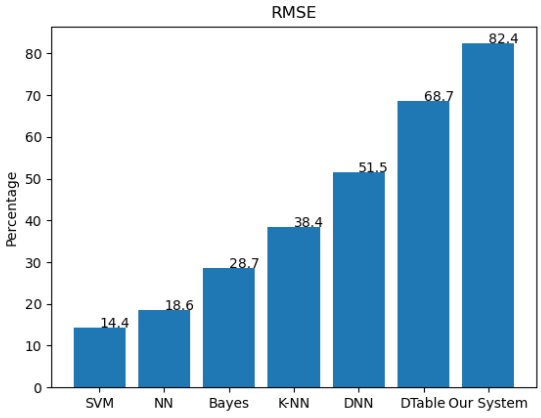

Figure 14. RMSE

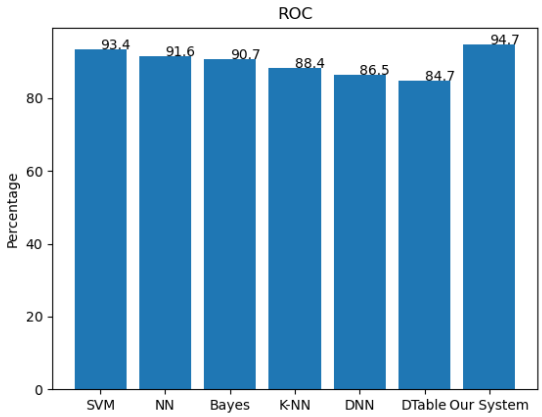

Figure 15. ROC

The values are considered for comparison with our system and their accuracy, Root Mean Square Error, and ROC have to be explained in table 3. Table 3 represents the overall results.

7. CONCLUSION

The COVID-19 virus spread can be avoided by taking precautionary methods suggested by the scientist but following the procedures continuously is a challenging task for all people. Moreover, suggestions are given to a common society of people for fighting against pandemic life. This research article provides the methodology to maintain the data which are generated by the human bodies of normal people and taken for analytics purposes with the threshold values defined by the standards. Moreover, The monitoring of the day-to-day activities of a human creates a positive social impact on the people during such pandemic situations. This work identifies the parameters of a patient and identifies the effects of such factors. Hence the system keeps monitoring to avoid such factors eventually. A lot of new innovative methods have come across in this pandemic situation but this method provides a better way to detect COVID-19 at an early stage with IoT wearable devices. It is a cost-effective system and portable to all places easily. Maintenance of this device is comparatively easier and the power source to this system is either a rechargeable battery or a battery backup generally. This system provides effective data management framework in IoT during pandemic life. This system categorized the affected people's day-to-day actions and advise them not to enter into various zones often. The entire system gives a high rate of detection of virus-affected persons and response to the users in a very short time. Notifications are sent to a limited number of persons with the location details immediately.

8. FUTURE ENHANCEMENT

The proposed system handles only limited data since the person travels only to limited areas and distances. In the future, this system will work on longer distances and a huge

TABLE III. Performance Results Summary

Algorithms	Accuracy Percentage	Root Mean Square Error	ROC
SVM	93.95	25.64	92.9
Neural Network	91.25	23.29	94.8
DNN	92.6	27.91	94.1
KNN	92.4	28.36	93.9
Naive Bayes	91.5	29.68	94.1
Decision Table	91.85	21.89	94.8
Our System	94.2	29.15	95.0

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 which may not be suitable for such age group. The next level is planned to design for them also to easily wear this device. Generally monitoring and controlling are performed in this system by GPS, GSM modules attached to the device. The future device will consist 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 to the number of people responding. In the future, the notifications will be sent to more people, especially the people who are nearby thereby facilitating him to give first aid at the earliest so as to avoid delays. This application-oriented research work is further carried out for blind people also to include various cloud storage modules [23] [24] 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 accuracy. In the future, the analytics will be carried out using big data analytics by implementing the technique in the device and used for all kinds of people where the data is managed using IoT framework effectively [25].

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