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*Original Article*

# A Cloud-Centric Real-Time Telemonitoring System for Cardiac Patients based on the Internet of Medical Things

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***Abstract*** *- The convergence of Internet-based technology with primary care utility is critical for the worldwide amalgamation of quality medical management and its accessibility. Innovation has remained a significant aspect of medical care, allowing physicians to employ a variety of instruments to examine, administer, and observe patients. This paper's central emphasis is on e-health data collection, conveyance, and surveillance apparatus. The wireless monitoring system monitors patients' medical metrics and communicates them to the furthest edge via the ZigBee gateway. This paper introduces an IoT-enabled smart e-healthcare system that can continuously monitor patients' vital signs and the real-time room environment where patients are currently positioned. This system collects data from the hospital premises using five sensors: the body temperature sensor, the heartbeat sensor, the room temperature sensor, the CO2 sensor, and the CO sensor. For each situation, the percentage of errors in the developed scheme is less than 2%. The patient's situation is relayed to medical personnel via a portal, where they can monitor, process, and analyze the patient's real-time situation. A low-power communication device and an embedded smart IoT system are being designed and developed with the goal of covertly gathering physiological metrics without interfering with daily life. Sensor-based data analytics using machine learning methods were used in this study to identify predictors and/or sudden abnormality indicators accurately. The data for heart rate and body temperature is analyzed using the bio-medical sensors embedded with an ARM Cortex-A7 microcontroller. For the benchmark accuracy of the dataset, a detailed calculation of experiments in the Internet of Medical Things (IoMT) with various machine learning techniques is compared. It has been exemplified through extensive testing that the recommended procedure outperforms machine learning methodologies with a 15% increase in accuracy, facilitating rapid alarms to prevent the aftereffects of abnormalities if they occur, which the system without the utilized methodology lags. Cloud storage allows for the analysis of parameters regarding patients. The error between observed and actual data is analyzed to validate the proposed Internet of Medical Things model. The performance of the proposed method is further identified by using various classifications, like decision trees, discriminant analysis, support vector machines, and Naive Bayes, for detecting any variation from normal data or disorder on real-time datasets.*

***Keywords*** *- E-health, Internet of Medical Things, ARM-Cortex-A7 microcontroller, ZIGBEE, Machine learning techniques.*

## 1. Introduction

The Internet of Things (IoT) has arisen to give people more comfort and an improved way of living. Numerous technological principles, including person-to-person and device-to-device connectivity, computing, and detectors, are all part of the Internet of Things. The information streams beneath such solutions are among the secrets to the IoT's effectiveness. Today, society has a majority of young people who are popularly called "Millenials." These youngsters are facing many issues, which is a challenge for any developing society. Most health issues are due to a lack of fitness awareness and exercise, poor eating habits, etc. It leads to severe chronic disorders. Currently, the whole world is facing this issue on a large scale. Previously, many traditional efforts have been made to control this problem, though it can be easily observed that these endeavours had very little or no effect on the healthcare sector. So, a patient's fitness must be assessed by detecting his body's parameters in advance. This can be done by deploying a health care unit to the patient's body and continuously monitoring his body using various biosensors. This real-time monitoring can be made more effective by equipping an IoT module to it, enabling the data to be accumulated in the cloud for analysis. The data is sent to the doctors and clinicians, and a regular fitness check can be conducted. "The Internet of Things (IoT) is an emerging trend in leading-edge innovations that has the ability to influence the entire business spectrum. It is defined as the connectivity of individually identified sections and equipment within recent internet technology, including positive considerations. The increased interconnection of multiple gadgets, networks, and applications, which extends above and beyond equipment-to-equipment situations, is perhaps one of the attractions" among the most appealing implementation domains for the IoT in healthcare. Numerous diagnostic methods, like remote patient diagnosis, workout regimens, serious illnesses, and eldercare, might be enabled by the Internet of Things [2]. IoT requirements, such as data management, data processing, wireless connectivity, and healthcare effectiveness, are inherently based on information that poses a number of issues [3,4]. Information is compiled, evaluated using a framework methodology, and a conclusion is drawn at the end. Information is crucial throughout the workflow, and careful implementation and synchronization become key when it comes to healthcare. Information is retrieved from various detectors in healthcare, including implanted detectors, monitoring devices, etc. Currently, there are 3.7 million gadgets in use to detect distinct organs and systems, and this number is expected to grow significantly over the next few years [5]. The major contributions to the work are listed below:

- In the proposed scheme, a wearable health monitoring system equipped with a microcontroller unit and various biosensors is connected to the patient's body to monitor various health issues seamlessly.

- The novel approach allows the acquisition of data to form a medical database. It also favors the addition of new wearable sensor units, shows its compatibility with the Internet of Things technology, and allows data to be forwarded onto the cloud space for further examination and access by clinicians and doctors.

- The real-time monitoring system shows a minimum or no deviation of the monitored values from the true values obtained by directly using the instrument in analogue mode. The datasets obtained by real-time monitoring of a patient's body parameters are classified using four different supervised machine learning algorithms, namely, decision trees, discriminant analysis, support vector machines, and naive bayes, for the pre-detection of diseases or emergency situations. The accuracy, sensitivity, and F1-score performance metrics expressed in percentages are evaluated and compared for these four algorithms. The efficient working of the system can be seen, which will further add to getting prepared for any emergency situation and also will save the patient's life by sending the message immediately to the physician.

The article is structured as follows: "The literature regarding e-health monitoring systems is briefly discussed in the next section. Then the next section describes the workings and use of software and hardware units in the proposed method. A visualization of the experimental setup is also presented further. The results and discussion section evaluates the performance of the proposed model based on various parameters and presents a discussion on its performance by validating it with other similar state-of-the-art approaches in the e-health monitoring domain. The final section concludes the paper and gives an idea of how this work can be further extended".

## 2. Related Research on IoT-based E-Healthcare System

Amongst numerous applications enabled by the Internet of Things (IoT), reasonable and related customer interaction is especially important. Connection devices, whether mounted on the bodies or embedded in our daily environment, alter the big affair of rich data demonstrating our health and cognitive status. If continuously captured, gathered, and profitably strip-mined, such data will cause a favourable transformative alteration inside the medical insurance scene. "In this article, we will use Raspberry Pi to analyze the patient's heart rate, body temperature, respiratory rate, and body postures. After attaching the Raspberry Pi board to the Web, it functions as a server. The host then delivers data to the website immediately. The variables are then monitored using a portal from anywhere in the globe using PCs, smartphones, and so on".[1,2,3].

The Internet of Things has expanded in a wide range of application fields, including clinical care and health services. These technologies enable physicians and patients to forecast and treat numerous ailments based on the results properly. The importance of such a study is how data generated by sensor-enabled devices in the Internet of Things healthcare or medical care environment is handled and categorised. [4-8]

"The research study includes a current evaluation of several algorithms such as SVM, Nave Byes, Decision Tree, KNN, and others that were used to categorise data received from sensor-enabled equipment in the healthcare or medical care context of the Internet of Things using a comparison".[48]

Investigators all around the globe have begun to investigate multiple technology methods to enhance medical assistance in a way that enhances existing infrastructure by using the IoT's possibilities. Several papers on e-health data procurement systems have been reviewed and are included as follows: Some of those who have contributed to this work are discussed ahead in this section. Various healthcare domains and applications have been introduced to benefit the health of human beings [10, 12].

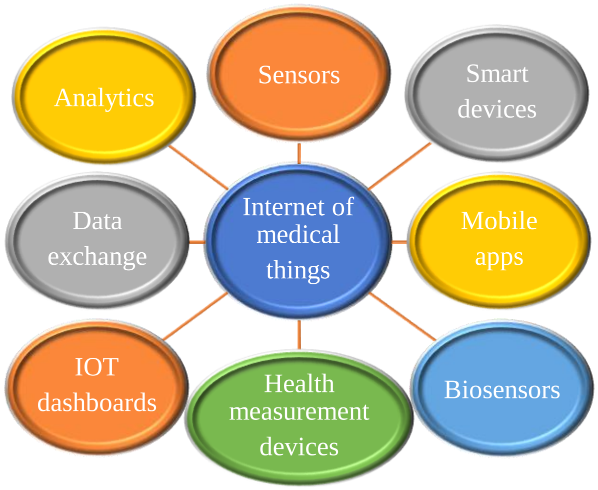


**Fig. 1 Internet of medical things[11]**

In [13-16], the research focuses on the architecture of oxygen level measurement and intensity computation and the statistical diagnosis of being a COVID-19 sufferer while maintaining patient confidentiality. The approach was implemented using a probability arrangement with oxygen saturation observations related to IoT architecture and blockchain considerations and an inter-modular function, hummingbird technique, and photon-hash to reduce computing complexity.

The author in [17,18] discusses the application of an Internet of Things-based eHealth infrastructure for local and remote healthcare management as well as the service's capacity to capture information from the detectors. The paper includes several elements of Internet-of-things medical technologies and numerous medical network designs and frameworks that allow access to the IoT backbone and ease the transmission and reception of health information.

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In [16, 21-23], the investigator included a healthcare information identification in IP packet headers at the module level, modified QoS technology at the connectivity gateway standard, and gave healthcare information network navigation the utmost importance depending on the healthcare information identity visible at router QoS. The study's findings show that healthcare transmissions with identification may transit to physicians with 80 percent less delay than packages with no identifier. Furthermore, the suggested data procurement systems have been reviewed and included as follows: Some of those who have contributed to this work are discussed in this section.

The analyst has established a great perspective on advancing the healthcare community at 4.0. As a result, the paper discusses the recent framework for wireless body sensor connections, highlighting its importance and how it might encourage the growth of next-generation healthcare systems utilising evolving technologies such as machine learning and a comprehensive review has been accomplished of some of the various architectural applications[25-26].

In [27-30], the research examines recent advancements in IoT-based human asset contexts and healthcare structures such as mHealth, 6LoWPAN-based layouts, and multisensory-based structures, approaches that detect sugar levels, cordless thermometers, pulses, and electrocardiograms. By giving a unique identifier for each patient, the internet of things enables the customization of medical services.

Physicians can go beyond the territorial barriers of their practice and give clinical training to nursing teams in rural areas [31,32].

"The healthcare industry comes with its own set of IoT problems. There is a lack of EHR connectivity and uncertainty concerning data licensing. As a result, attackers or hackers can create disruptions to the infrastructure. IT workers' role is to raise healthcare practitioners' understanding of the issues surrounding enabling IoT technologies [33,34].

An artificial intelligence (AI) enabled intelligent health care system for early prediction of diseases using the Ridge Adaline Stochastic Gradient (RASGD) Descent Classifier is proposed. This system guarantees 92% accuracy when compared to other state-of-the-art techniques. Above all, these methods use IoT platforms and various machine-learning techniques to analyse medical data. However, none of the methods discusses the hardware and software efficiency, computation cost, or complexity of the system". The proposed method uses the Raspberry Pi (BCM2836) microcontroller, which has many inbuilt modules and promises high performance and fidelity.[35-40]

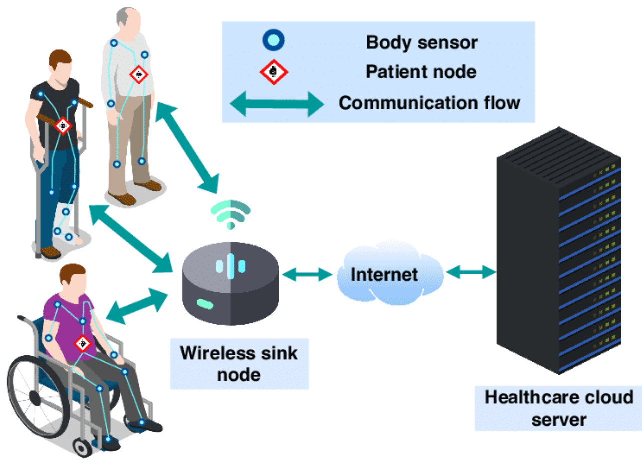



**Fig. 2 Healthcare Network [24]**

The healthcare sector uses more and more Internet of Things (IoT) technology. Among the most common IoT applications in the field of intelligent medicine are the depiction of inventory control, the digitalization of health information, and the digitization of medical treatments [41-44].

Examine modified layered application protocols for applicable real-time apps to improve performance and conventional and contemporary IoT application layer protocol developments. “Machine learning offers ways to make protocols intelligent and capable of dynamic adaptation because it is unrealistic to change the nature of protocols for each application” [24-44].

The implementation of IoT for healthcare includes certain current trend analyses and predictions for future advancements in healthcare systems [46-47].

## 3. System Architecture

“Our system's power relies on currently used wireless communications to give users the most mobility and minimal power possible as they engage in physical activity. Additionally, we have deployed user-friendly, compact, and smart IoT devices like wristbands and smartphones. We conducted a comprehensive series of experiments for analyzing and differentiating between normal and abnormal parameter variations and found results from embedded sensors. The subjects wear the integrated sensors for sensor-based medical records”.

**Table 1. Qualitative and Quantitative comparisons of existing functions based on distinguished features.**

| Approach | Use IoT | Mobility | Low Power System | Cyber-Physical | Cost Effective | Average Max HR | Approximate Accuracy |
|---|---|---|---|---|---|---|---|
| PatientsLikeMe[27] | **No** | **Yes** | **Yes** | **No** | **No** | **160** | **90%** |
| Omnio [28] | **Yes** | **Yes** | **Yes** | **Yes** | **No** | **140** | **80%** |
| Daily Strength [29] | **Yes** | **Yes** | **Yes** | **No** | **No** | **156** | **85%** |
| Everyday Health[30] | **Yes** | **No** | **No** | **No** | **No** | **144** | **85%** |
| Mancini [31] | **No** | **No** | **No** | **Yes** | **No** | **151** | **87%** |
| Qardiocore [32} | **No** | **No** | **No** | **Yes** | **No** | **135** | **78%** |
| RMHM [33] | **No** | **No** | **No** | **Yes** | **No** | **162** | **82%** |
| Stecker [34] | **No** | **No** | **No** | **Yes** | **No** | **167** | **77%** |
| SEHMS [35] | **No** | **Yes** | **No** | **Yes** | **No** | **155** | **78%** |
| PHM [36] | **Yes** | **Yes** | **No** | **Yes** | **No** | **145** | **70%** |
| Maksimovic´ [37] | **No** | **No** | **No** | **Yes** | **No** | **155** | **85%** |
| Kavitha [38] | **Yes** | **No** | **No** | **Yes** | **No** | **156** | **68%** |
| Communicore [39] | **No** | **No** | **No** | **Yes** | **No** | **148** | **72%** |
| Sun [40] | **No** | **No** | **No** | **Yes** | **Yes** | **160** | **75%** |
| Jagtap [41] | **No** | **No** | **No** | **Yes** | **No** | **148** | **72%** |
| CNN Model[42] | **Yes** | **Yes** | **Yes** | **No** | **No** | **145** | **93%** |
| Hybrid PCA-GWO[43] | **Yes** | **No** | **Yes** | **Yes** | **Yes** | **150** | **99%** |
| Sudarshan[44] | **Yes** | **No** | **No** | **Yes** | **Yes** | **155** | **99%** |
| Our Approach | **Yes** | **Yes** | **Yes** | **Yes** | **No** | **255** | **99%** |

While the individual is going for his or her daily activities, the implanted ECG, heartbeat, and temperature sensors continuously collect the values. “The smartphone will evaluate the data after receiving it through a Zigbee communication connection to determine whether the user's normal or abnormal state. The system platform executes a quantitative heart rate analysis and offers the user the option to view real-time charts of their ECG signals and body temperature. We must create a standard for typical stability to identify anomalous patterns. A number of parameters, including temperature, heart rate, RR intervals (the time between two successive R peaks in an ECG signal is known as the RR interval), and ST segments (the ST segment is the flat area of the ECG signal between the ending of the S wave and the beginning of the T wave), will be produced through quantitative and qualitative studies of bodily stability and pulse symmetry”. The time span between ventricular depolarization and repolarization is represented by it. The next step is to create an early warning system to watch for abnormalities in those metrics. Despite the fact that the system continuously analyses ECG patterns, the designed process only generates a warning when the user's ECG patterns and body temperature cross a certain threshold, and the user could potentially be in a critical stage. The physician receives a warning from the system at that time, either in the form of a message or a vibrating alarm.

## 4. Proposed Methodology

For healthcare management, IoT sensors may detect actual information. “Hypertension, hypoglycemia, and obesity are all monitored using these devices”. The Internet of Medical Things (IoMT) will encourage individual treatment and good quality of life. Local patient devices and management, equipment connection and database administration, and informatics services are the three technological types employed in the "internet of things.". “Remote health monitoring and healthcare service management are two examples of IoT innovation. Cellphones are becoming increasingly important in remote patient monitoring”. A variety of healthcare Internet of Things systems have been developed for patient record administration, telehealth supervision, and cellular health care [9, 10].

Figure 1 depicts an example of IoMT [11]. There are several IoT implementations in the medical field, ranging from remote access systems to sensing devices and pharmaceutical device interfacing. Individuals, relatives, caregivers, and clinicians all benefited from the technology. Numerous healthcare tools, like electrocardiography, monitoring of glucose levels, and oxygen diffusion monitoring, can benefit from IoT in medical care [12, 13, 14].

The proposed system's basic concept is continuous online monitoring of patients and patients' room conditions. “The healthcare monitoring system uses three-stage architectural features as a consequence:

(1) the sensor module,
(2) the data processing module, and
(3) the web user interface.

A patient's body and its surroundings are monitored physiologically using connected sensors. “The ARM Cortex-A7 subsequently processes the data before being transmitted to the gateway server. The Amazon Web Server is employed for the web user interface's graphical representation and interpretation of the collected data”. The Amazon Web Server displays the real-time status and progression of transactions at the moment. With the help of the HTTP protocol, communication between a Wi-Fi module and a web server is made simple. The HTML interface design updates every 15 seconds, enabling real-time patient tracking. It is clear that all of the sensors are being used to gather information about the healthcare context”.

➢ *Raspberry Pi*

The Raspberry Pi is a type of microprocessor to which all the sensors are attached. The Raspberry Pi serves as the system's brain once these ( heartbeat, temperature, and gas) sensors are connected. Sensor data is gathered by the Raspberry Pi and remotely sent to IoT websites. The board has its own processors and Wi-Fi. The IoT website is then connected to the sensor output. Any device that supports a network can access the data. There, the data is being shown graphically, and since it uses a channel-based approach, a password is required each time you access it.

On the other hand, it describes the several methodologies and algorithms employed for categorizing the occurrence of accuracy, F1-score, and sensitivity in the IoMT domain. The IoMT system comprises a variety of smart objects that track patient health and transmit periodic updates to the doctors so they may stay in frequent proximity even while they are far away. Although the devices are intelligent enough to gather sensitive data and send it to a storage location like a cloud server, they are also intelligent enough to analyze the data to determine whether it is being transferred appropriately or if any erroneous data is being transmitted in storage. When an IoMT environment is used, there are many ways to analyze and compare feasible studies.

Our model relies on these methods to determine the accuracy and sensitivity of real-time data. We are aware that a large amount of data will be produced in an IOT context. There will be significant data flow both within and between networks. We need to use a variety of machine learning algorithms like decision trees, support vector machines, discriminant analysis, and Naive Bayes to examine the accuracy of the data in order to handle such massive volumes of data and optimize usage and analysis to be very accurate for improving performance.

The learning methods are helpful for classifying, minimizing dimensions, and finding anomalies. For various dimensions and large-scale data, manual feature engineering does not work, but a classification learning approach can quickly understand such enormous data.

Here we provide an introduction to the IoMT environment for different classifiers to check for better performance and accuracy by the algorithms.

### *4.1. Classification Models*

Employing the authentic classifiers Decision Tree (DT), Nave Bayes (NV), Discriminant Analysis (DA), and Support Vector Machine (SVM), the IoMT environment for dimensionality reduction is further examined to assess its efficiency over classification. The three commonly used measures of accuracy, specificity, and sensitivity are used to analyze the performance of the different classifiers. The effectiveness of the classifiers is examined.

#### *4.1.1. Decision Tree Classifier*

The Decision Tree classifier's performance was higher than any other classifier in both datasets. The obtained average accuracy is 99.1%, the average sensitivity is 92.5%, and the average F1-score is 90.1% for the heart rate data set. When using the same DT classifier for the temperature dataset, the average accuracy is 99.1%, the average sensitivity is 97.4%, and the average F1-score is 98.1%.

#### *4.1.2. Discriminant Analysis Classifier*

The performance of the Discriminant Analysis classifier as an average performing classifier in heart rate datasets is 91.2%, the average sensitivity is 89.3%, and the average F1-score is 80.5%. When the same DA classifier is used for the temperature dataset, up to 500 instances can be Average accuracy is 91.2%, the average sensitivity is 92.8%, and the average F1-score is 94.4%.

#### *4.1.3. Naive-Bayes classifier*

The efficacy of the Naive-Bayes classifier as a conventional model is as follows: when the NV classifier is used as a conventional model over the real-time dataset, the obtained average accuracy is 87.2%, the average sensitivity is 86.3%, and the average F1-score is 78% for heart rate datasets up to 500 instances. When the same NV classifier is used for temperature data sets, the average accuracy is 87.2%, the average sensitivity is 91%, and the average F1-score is 91.2%.

#### *4.1.4. Support Vector Machines Classifier*

The performance of the Support Vector Machine classifier was the lowest-performing classifier in both datasets. The average accuracy is 84.5%, the average sensitivity is 83.2%, and the average F1 score is 72.3% for the heart rate dataset. When the same SVM classifier is used for temperature datasets up to 500 instances, the average accuracy is 84.5%, the average sensitivity is 86.2%, and the average F1-score is 89.5%.

## 5. Software Employed

### *5.1. Raspberry Pi*

The Raspberry Pi comes without an operating system. It requires New Out of Box Software, commonly known as NOOBS (NOOBS stands for New Out Of Box Software). Setting and configuring your Raspberry Pi is a snap with the aid of this software configuration. When NOOBS first starts up, you can choose from a number of operating systems.

The specified operating platforms are determined on the Raspberry Pi model. For the sake of this study, we will stick to the currently frequently used operating systems present on the current Raspberry Pi devices. This included RISC OS, Open ELEC, Raspbian, Windows IoT Core, and OSMC at the time.

The eHealth system acquired comprises numerous software applications designed using a flexible modular development methodology to accept a variety of embedded equipment with minimal driver compatibility. A confluence of modern healthcare monitoring systems and digital technologies has evolved as the Internet of medical interventions and clinical response to the IoT's emergence. RFID, GPS, and remote monitoring are among the detection devices.

Device interface and real-time assistance technologies enabled by IoMT are assisting the health sector in improving accessibility, cost, dependability, and efficiency. Conventional healthcare industries turn intelligent when they are linked to the Internet and may gather additional information, provide information on developments, facilitate information treatment, and provide patients with greater dominance.

[5], For healthcare management, the Internet of medical devices can detect actual data. Hypertension, hypoglycemia, and obesity are all monitored using these instruments. Integrated patient monitoring and management, equipment connection and database administration and research technologies will all be promoted by the Internet of Things [6, 15, 16].

One can acquire crucial data about ageing patients remotely by utilising the prior method of using PC gadgets as data acquisition (DAQ) equipment. An existing platform utilises Bluetooth devices to detect the temperatures and pulses of multiple patients and conduct rapid responses. This paper’s central emphasis is on electronic medical possession, communication, and surveillance. “The health framework of patients is maintained by a wireless sensor and relayed to the receiver end via GPRS.

The microprocessor monitors the information obtained at the other end. If any of the characteristics are anomalous, the GSM component is configured to transmit SMS to the physician's cellular device and refurbish the information on the website".

## 6. Experimental Setup

"The health parameters of patients are analyzed by wireless sensor nodes and relayed to the remote end via GPRS. The microprocessor monitors the data received at the other end. If any of the indicators are unusual, the GSM module is programmed to send an SMS to the physician's cellphone and modify the information on the website. The approach used in this research is designed for individuals who are not in a severe condition but still need to be checked on a regular basis. Whenever a catastrophic state arises, the programme will transmit an emergency notification to the physician. Figure 2 illustrates various components of an e-health monitoring system".

As illustrated above, the power supply provides the necessary power, consisting of a step-down transformer, and then rectifiers are employed for conversion from ac to dc, and we utilise a Raspberry Pi charger to deliver electricity to the Raspberry Pi. The microcontroller is the control unit. The IEEE 802.15.4 Personal Area Network work specification governs Zigbee, a novel wireless automation technology. It is principally intended to complement non-standard solutions in a diverse variety of applications.

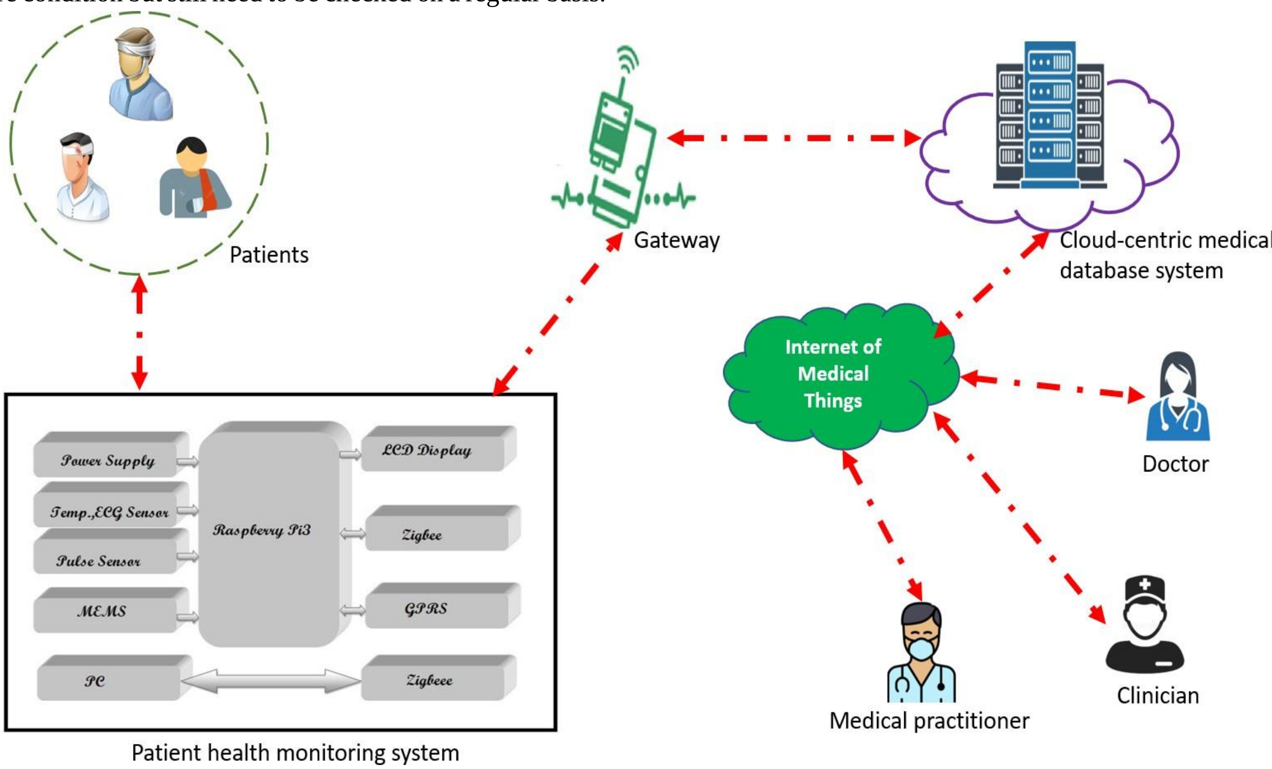



**Fig. 3 Block diagram of the proposed system**

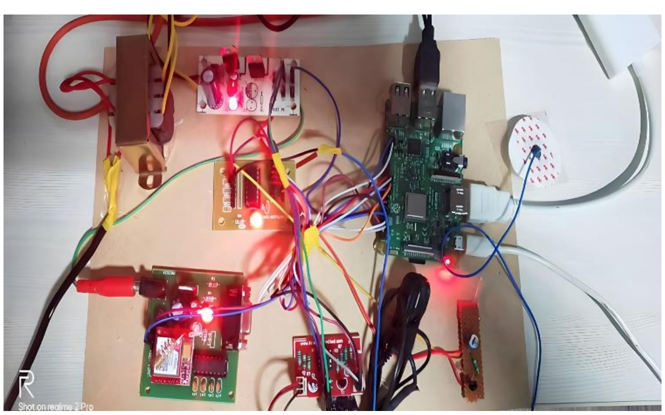


**Fig. 4 Hardware setup**

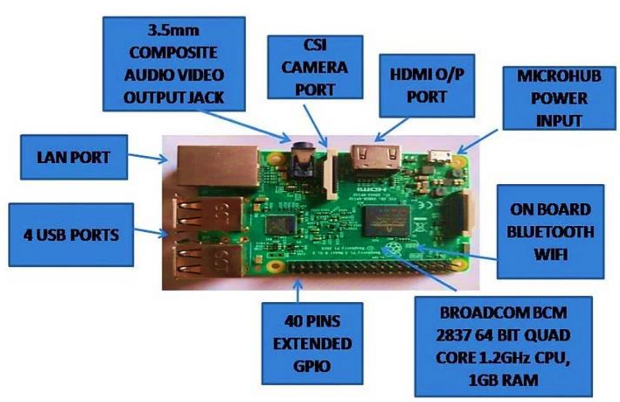



**Fig. 5 RASPBERRY PI (BCM2836)**

It presently runs in the 868 MHz range in Europe at a band of 20 kbps, the 914 MHz band in the United States at 40 kbps, and the 2.4 GHz ISM bands globally at a maximum rate of 250 kbps. ECG sensing probes are positioned on the person's body, and a pulse sensor (or heartbeat analyzer) into which a fingertip is inserted produces a digital output of the heart's beat. During each pulse, it operates on the concept of high manipulation by blood circulation through the fingertip, and the LED blinks at the rate of one heartbeat.

With MEMS (Microelectromechanical System) being utilized to monitor the patient's body position, interaction will occur with the aid of serial communication between the GPRS modem and the microcontroller. A MAX 232, a sequential driver, is used to connect the modem to the microcontroller. The GPRS module allows you to send data to the website immediately. The system block diagram for the e-health monitoring system is illustrated in Fig. The hardware setup for the scheme is depicted in Figs. 4 and 5.

## 7. Result and Discussion

The Raspberry Pi 2 Fig. 4 has a computational powerof six times that of earlier versions. In this second generation of Raspberry Pi, the BroadcomBCM2836 CPU,a capable ARM Cortex-A7-oriented quad-corechipset that runs at 900MHz, has been improved.

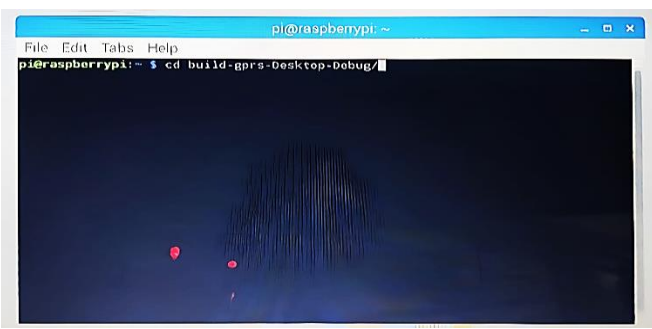



**Fig. 6 Commands to run the raspberry pi code**

The storage capacity on the device has been increased to 1 GB. The command to be implemented to run the code for Raspberry Pi is illustrated in Figs. 6, and run the code for Raspberry Pi is illustrated in Figs. 6 and 7. Fig. 6 depicts a Raspberry Pi console to run the command; we can define the sensors for sensing the body parameters through commands. Figure 7 illustrates Raspberry Pi's UI. It shows the various characteristics, i.e., meaningful data gathered by multiple sensors affixed to the sufferer's body. Every detector has an inherited component that may operate independently of the rest of the unit, resulting in increased reliability. Sequential connections are used to obtain all the information determined by the operating system for sensor connections. Although not all sensing devices access operating systems, they capture information and might be operated in an indistinguishable way.

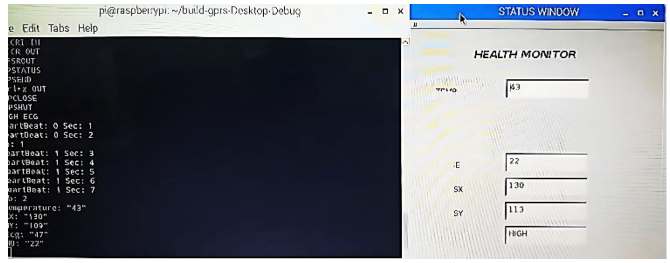



**Fig.7 Result of graphical user interface**

The graphical user interface window exhibiting different parameters and the status of individual sensing devices is illustrated in Figs. 8 and 9. Fig. 8 depicts the embedded smart IoT portal for the system so that healthcare personnel and guardians can continuously monitor the patient no matter where they are. It is also easy for remote patient observation. It communicates with sensors through a microcontroller and displays real-time data. It is also beneficial when some abnormality occurs while observing a patient so that immediate treatment can be provided easily. Fig. 9 depicts the web portal interface when the patient's condition is normal and when a sudden abnormality occurs.


**Fig. 8 Figure displaying the real-time embedded system of healthy/normal outcome**

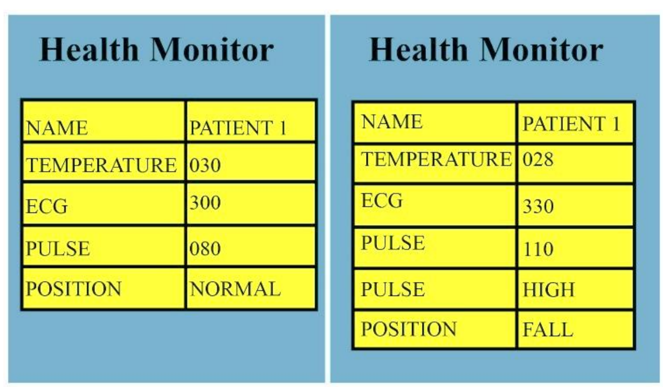



**Fig. 9 Healthcare information available on the website, including both healthy and drop states**

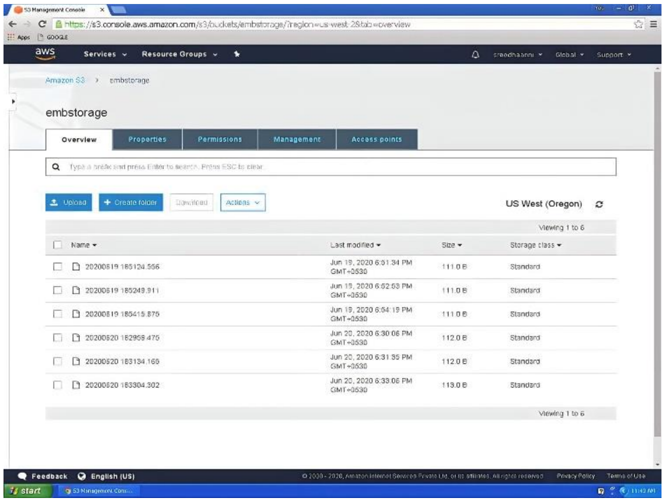


**Fig. 10 Cloud storage of the recorded data**

The respective window displays the current status of the health monitor along with the distinctive time of observation. The created web platform allows a home page from which the viewer can view the sensor panels by selecting the appropriate area. Additionally, upon visiting this screen, the visitor is given a summary of the most recent data gathered for each detector.

The collected data is crucial; therefore, the temperature, pulse rate, and ECG outcome are displayed simultaneously, along with the patient's status, which is either healthy or declining. The information is accessible via a connection linked to one of the Raspberry Pi's USB ports for ECG monitoring. After the observations are completed, and the ECG sensor is in connected mode, the historical data may be viewed. All additional sensors can provide real-time data by sending an alarming signal or text to the physician regarding the patient's present condition.

"The approach used in this research is designed for individuals who are not in a severe condition but still require examination regularly. The programme automatically transmits a warning alert to the physician whenever a catastrophic state arises. The collected information helps diagnose the patient's condition by sending texts and notifications to the physician's phone". The framework also recognizes that information can be stored in the cloud for extended periods of time and retrieved whenever and wherever required, which tends to maintain a log of an individual's overall well-being. The cloud storage window for the recorded data is illustrated in Fig. 10. Fig. 10 depicts the cloud storage, i.e., AWS storage of real-time data, with respect to the patient who is under examination. Data can be monitored, processed, and analyzed on a cloud server. We got some results from the patient by doing the example field test. We can compare and find standard measurements for the patients. The data on heart rate from analogue and developed machines that give actual and observed measurements, respectively, are given in Table 2. Table 3 depicts the body temperature data for both the analogue (actual) and developed (observed measurement) machines. Similarly, the ECG data is shown in table 4. The heart rate, temperature, and ECG report are similar on an analogue device.

Fig. 11 shows the observed and actual data for a patient's heart rate in bpm. It can be noticed that the observed data is likely to follow the actual data for a small number of subjects or patients. Fig. 12 shows the body temperature in *F* for different numbers of subjects. The observed data follows the actual data, which shows the reduction in error during sensor measurement. Fig. 13 presents an observed ECG report, whereas Fig. 14 gives an actual ECG report. It is observed that there is not much difference between the observed and actual ECG data. However, the error rate calculated for both heart rate and body temperature is depicted in Figs. 15 and 16, respectively. The bounds for error rate are less than 3% for heartbeat measurement in Fig. Similarly, in Fig. 16, the maximum limit of the error rate is 0.5% and less than 0.5%, which is considerably low.

Figs. 17 and 18 show the accuracy, F1-score, and sensitivity of various classification algorithms that are decision trees (DT), discriminant analysis (DA), naive bayes (NB), and support vector machines (SVM) applied on real-time datasets. "For the heart dataset, the instances are varied from 100 to 500, and the highest accuracy is given by the DT algorithm shown in Fig. 17(a)". Similarly, in Fig. 17(b) and Fig. 17(c), the F1-score and sensitivity for DT show the highest result, and for SVM, it shows the least value. The higher F1 score characterizes high precision and recall of the algorithm. Figure 18 indicates the classification done on the real-time body temperature dataset. The results in Figs. 18(a), 18(b), and 18(c) show that the decision tree algorithm again shows better performance than the other three algorithms.

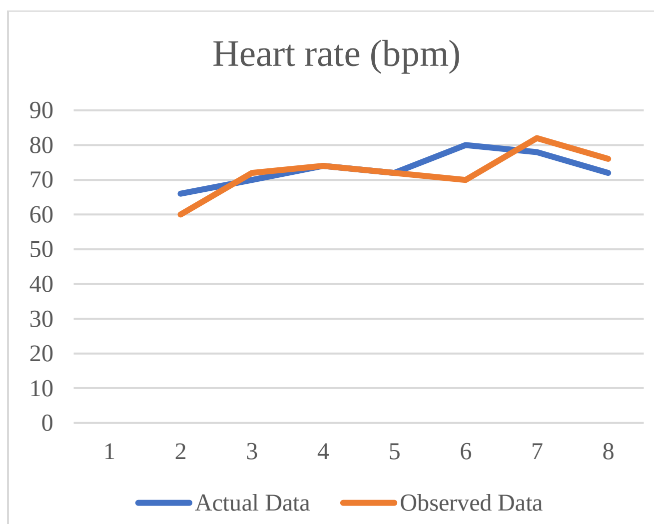


**Fig. 11 Analysis of observed and actual data forHeart rate with respect to the number of subjects**

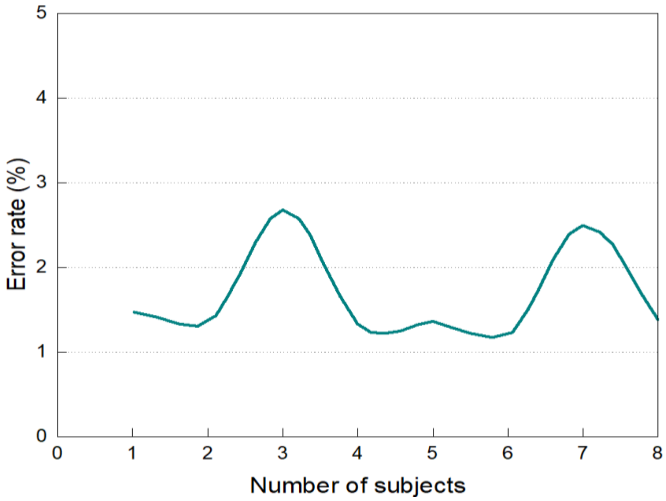



**Fig. 12 Analysis of observed and actual data forBody Temperature with respect to the number of subjects**

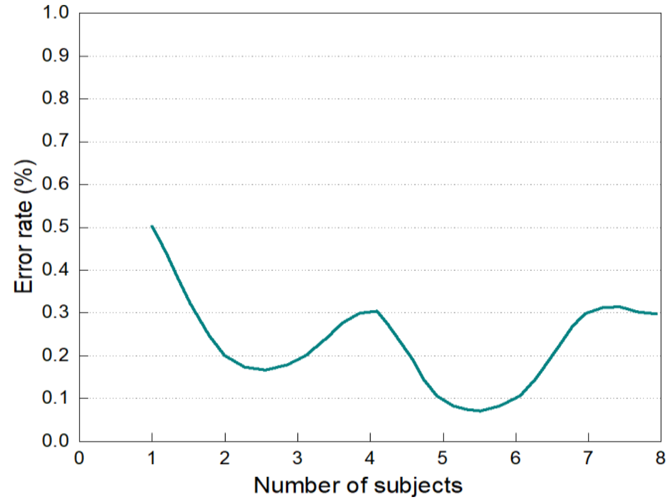



**Fig. 15 Error rate in percentage versus the number of subjects for real-time heart rate dataset**

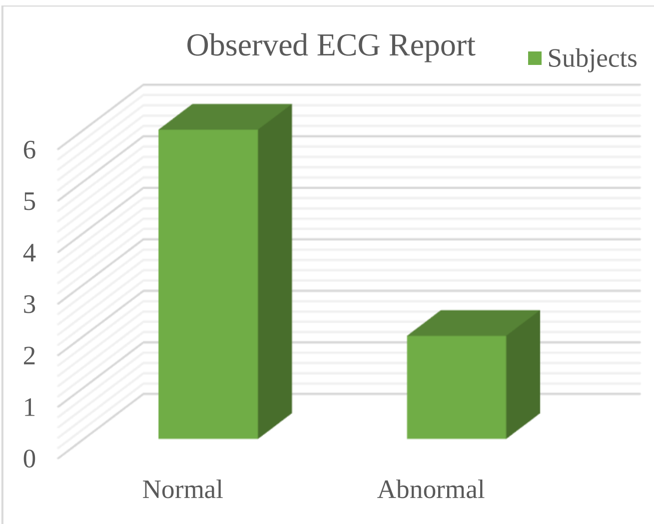



**Fig. 13 Observed ECG Report**

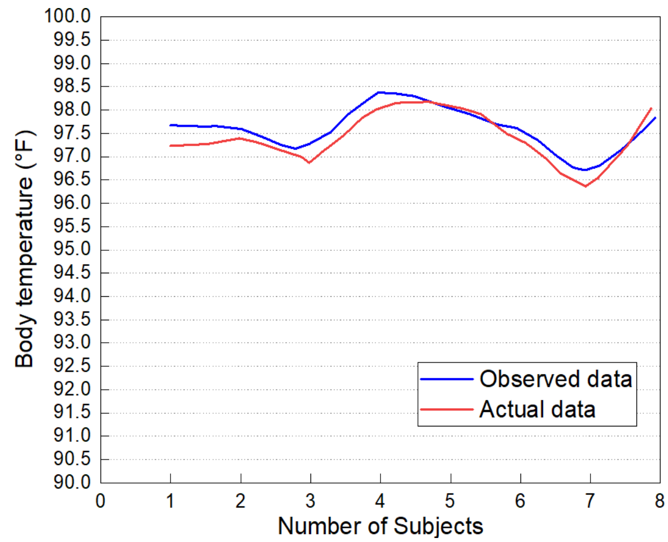



**Fig. 16 Error rate in percentage versus the number of subjects for real-time body temperature dataset**

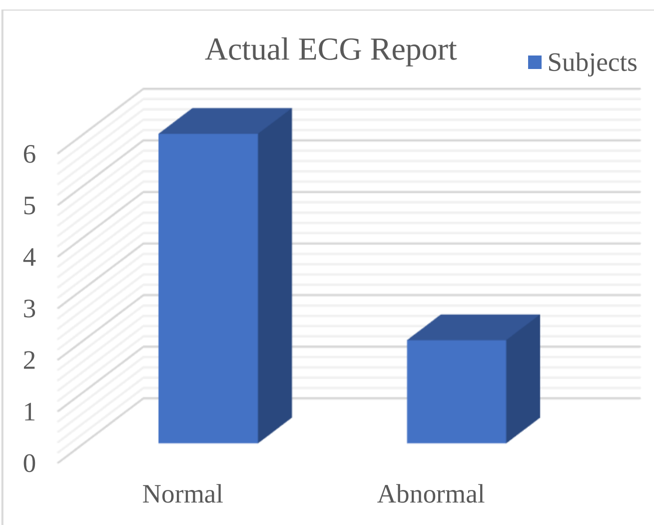
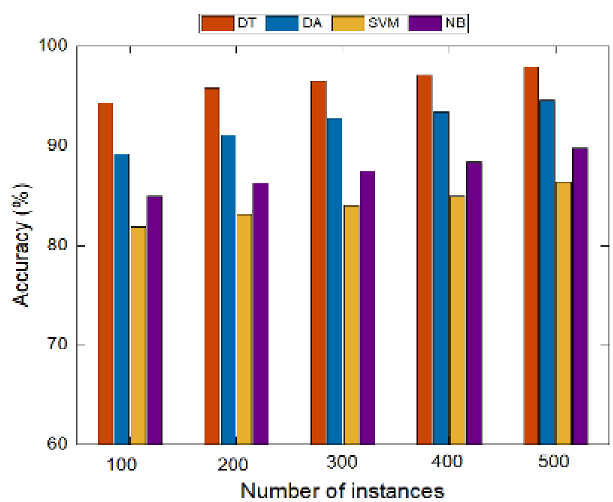
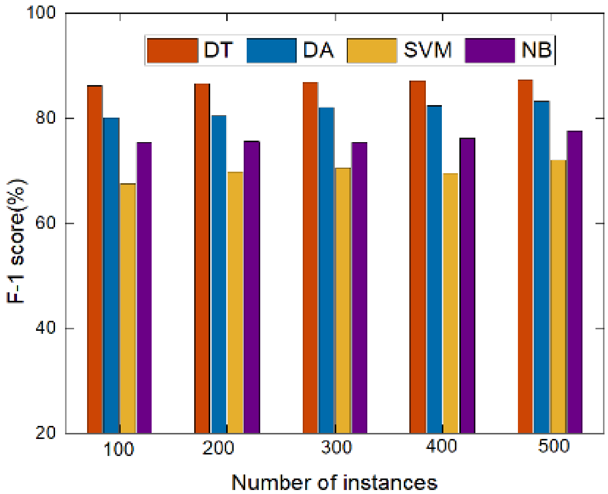


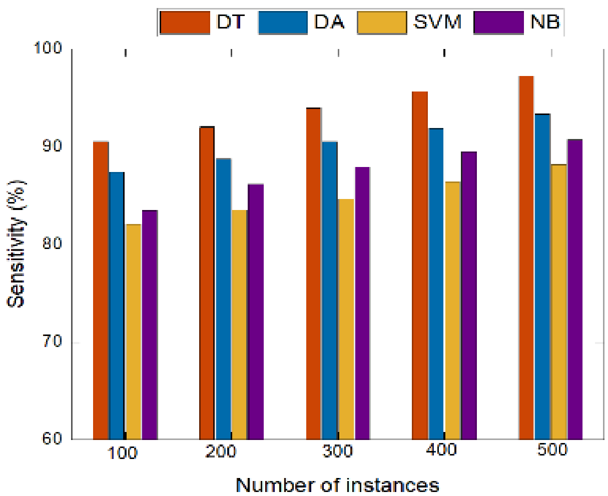

**Fig. 14 Actual ECG Report**




**(a) Accuracy**

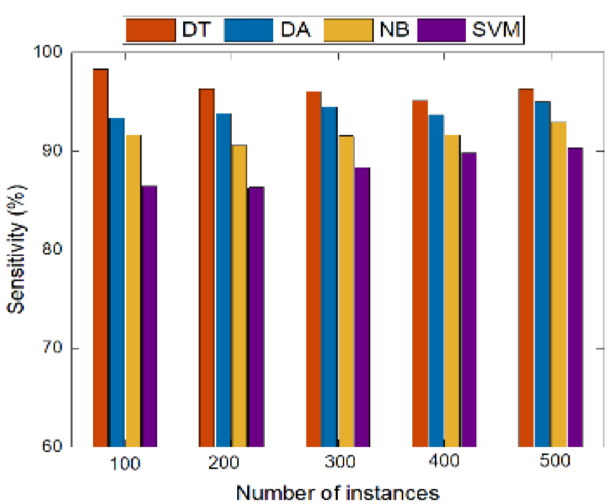



**(b) F1-Score**

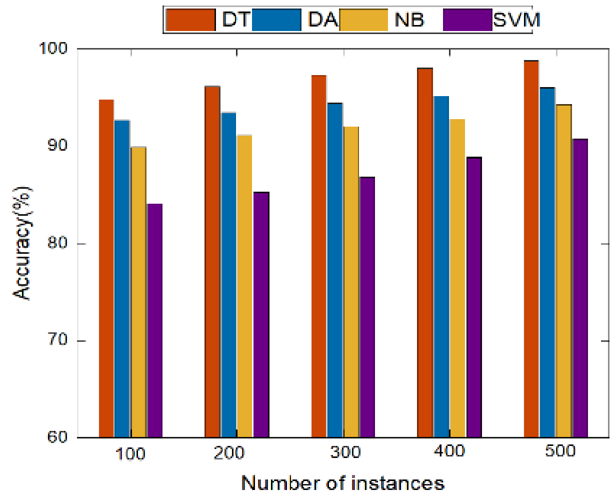



**(c) Sensitivity**

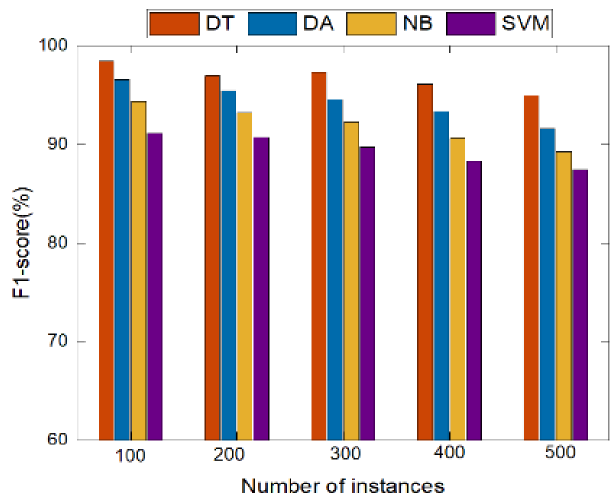
**Fig. 17 Classification efficiencies of four supervised learning algorithms for heart rate dataset**




**(a) Accuracy**




**(b) F1-Score**




**(c) Sensitivity**

**Fig. 18 Classification efficiencies of four supervised learning algorithms for body temperature data**

## 8. Conclusion

One of the primary industries where IoT may have, by far, the most significant commercial and cordial influence is healthcare. The Internet of Things will play an important role in individuals' examination, treatment, and recuperation. Combining IoT data collection and analytic applications will enhance health-care and eliminate individual mistakes. The system proposed "IoT enabled smart healthcare" to monitor patients' vital signs like body temperature and body temperature as well as some indicators of the health of hospital premises like humidity levels and gas concentrations of CO and $CO_2$. “For all instances of the existing healthcare system, there is an approximately 99% success rate between actual data and observed data.

Even though the experiments are carried out outside of hospital premises, actual medical staff have analysed the data and may track it in real-time.

In times of emergencies or epidemics, the technology can also assist nurses and medical professionals because it can quickly examine raw clinical records.

The developed system is very easy to use and design. The technology is especially helpful when treating infectious diseases like the novel COVID-19 coronavirus. The newly developed prototype will enhance the real-time healthcare system, potentially saving many lives from death".

The minimized collected data is classified under various popular state-of-the-art machine learning approaches, named Decision tree, Discriminant analysis Naïve-Bayes and Support Vector Machine. The outcome demonstrates categorically that the accuracy increases by 15% when the classifiers are used in association with the suggested IoMT as a function classifier. The amount of time needed to train the classification prototype is ideal for IoMT design and results in quicker notifications to medical professionals when the classification algorithm is applied in the IoMT environment to check the accuracy of real-time data. Decision Tree (DT) yields the highest result in the following algorithms, whereas SVM yields the lowest.

The decision tree approach again performs best compared to the other three algorithms, with a higher accuracy and F1-score indicating the algorithm's excellent precision and recall. The performance of the suggested framework for multiclass classification will be the focus of future research. Many future machine-learning techniques will be explored for the suggested intelligent framework.

Even while the system appears relatively big, it would be a tiny object with effective manufacturing in the near future. A video component could be implemented in the smart device to allow face-to-face consultations between patients and clinicians. Future research can focus on certain more metrics, such as the degree of diabetes, respiratory monitoring, etc., that are crucial in establishing a patient's status.

# Appendix 1

## Data Availability

The author is not able to share the real-time data used inthis manuscript. However, the author has presented the real-time sample datasets in Table 2 and Table 3.

**Table 2. Heart rate data collection from both devices analog (actual) and developed systems (observed)**

| Subjects | Actual data(bpm) | Observed data(bpm) | Error(%) |
|---|---|---|---|
| S1 | 67 | 68 | 1.49 |
| S2 | 70 | 71 | 1.43 |
| S3 | 74 | 72 | 2.70 |
| S4 | 75 | 74 | 1.34 |
| S5 | 73 | 72 | 1.37 |
| S6 | 80 | 81 | 1.25 |
| S7 | 79 | 77 | 2.53 |
| S8 | 72 | 71 | 1.39 |

**Table 3. Body temperature data collection from both devices analog (actual) and developed system (observed)**

| Subjects | Actual data(◦F) | Observed data(◦F ) | Error(%) |
|---|---|---|---|
| S1 | 97.3 | 97.8 | 0.51 |
| S2 | 97.4 | 97.6 | 0.21 |
| S3 | 97.1 | 97.3 | 0.20 |
| S4 | 98.1 | 98.4 | 0.31 |
| S5 | 98.2 | 98.1 | 0.10 |
| S6 | 97.5 | 97.6 | 0.11 |
| S7 | 96.5 | 96.8 | 0.31 |
| S8 | 98.1 | 97.8 | 0.30 |

**Table 4. ECG data collection from both devices analog (actual) and developed system (observed)**

| Subjects | Actual measure (ECG) | Observed measure (ECG) |
|---|---|---|
| S1 | NORMAL | NORMAL |
| S2 | NORMAL | NORMAL |
| S3 | NORMAL | NORMAL |
| S4 | NORMAL | NORMAL |
| S5 | ABNORMAL | ABNORMAL |
| S6 | NORMAL | NORMAL |
| S7 | ABNORMAL | ABNORMAL |
| S8 | NORMAL | NORMAL |

**Table 5. The software employed in the respective research.**

| S.no | Software employed | Explanation |
|---|---|---|
| 1. | Raspberry pi OS | • The Raspberry Pi does not include pre-installed system software.<br>• NOOBS is a system software administrator that enables downloading, installing, and configuring the Raspberry Pi effortlessly.<br>• NOOBS is an acronym that stands for "New Out Of Box Software." Raspbian isthe approved operating system for utilization with the Raspberry Pi. Raspbian isa GNU/Linux distribution created particularly for the Raspberry Pi. |
| 2. | Processing | Processing is an accessible programming framework and developing platform for modifying the code. Although extremely versatile and strong, it is mostly employed in the creative arts. The acquirement to create on display using coding is the focus of Processing. |
| 3. | Integrated development environment(IDE) | An integrated development environment (IDE) is a system software that brings together all of the resources that programmers ought to build and test the code. An IDEoften includes a code editor, a compiler or interpreter, and a debugger, all of which areaccessed via a unified graphical user interface by the programmer (GUI). An IDE canbe utilized as a stand-in application or even as an element of one or more appropriate technologies. The ui enables the programmer to gradually generate and run code,as well as handle reference application code in a uniform fashion. Most IDEs are built to work with arbitrator version control systems like GitHub or Apache Version. |
| 4. | QT creator | QT Creator is an application framework for designing and developing apps utilizing the QT application component. QT Creator enables you to make, execute, and dis- tribute QT apps for pc, integrated, and handheld devices. QT Quick Designer and QTDesigner are two existing graphical processors included with QT Creator. QT Quick may be used to develop logical, contemporary, and agile interface designs. You may use the inbuilt QT Designer to create a conventional user interface that is precisely organized and imposes a standard visual appearance. |
| 5. | Python | Python is an elevated, interpreted, dynamic, and object-oriented programming language. Python is intended to be a very understandable language. Python's structure and flexible typing, together with its interpretive orientation, make it an excellentchoice for programming and quick systems integration in various fields. Python provides a lot of coding patterns, spanning object-oriented, declarative, usable, and iterative coding. Python provides the Object-Oriented programming approach, which abbreviates code into entities. |

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