Internet of things based electrocardiogram monitoring system using machine learning algorithm

Abstract

It will provide timely and efficient healthcare services to rural areas, where healthcare infrastructure is inadequate. The system will also assist medical professionals in accurately diagnosing and treating heart

diseases. The monetization component refers to the potential revenue generation of the system through subscriptions, partnerships with healthcare providers, and other means. Overall, the smart IoT-based ECG monitoring system has the potential to improve cardiac health outcomes and alleviate

poverty-related healthcare disparities in rural Bangladesh.

Introduction

The technology-driven healthcare system has helped reduce the mortality rate of various diseases, including heart disease. Telemedicine is also an emerging trend that is gaining popularity in the healthcare system. Patients who live far away from healthcare centers and hospitals can communicate with doctors online and receive medical advice and prescriptions. This mode of healthcare is especially helpful for patients with chronic diseases like heart disease.

Moreover, raising public awareness about the importance of a healthy lifestyle, regular exercise, and a balanced diet can also help reduce the prevalence of heart disease. Lifestyle interventions can prevent the development of heart disease in healthy individuals and can also improve outcomes in patients with existing heart disease.

In conclusion, heart disease remains a significant health concern in Bangladesh, and efforts are needed to improve the efficiency of cardiac disorders and reduce the mortality rate. A technology-driven healthcare system, telemedicine, and public awareness about lifestyle interventions are some of the strategies that can help achieve this goal.

The use of IoT technology in cardiac monitoring has shown great potential in identifying cardiac problems early and managing them effectively. The development of portable cardiac monitoring devices utilizing ECG technology and unintrusive sensors connected to the body has made it possible for individuals to monitor their cardiac health regularly. The IoT-based framework provides a global system for mobile communication and real-time monitoring, which reduces time waste in ambulatory services and hospitals. This technology has the potential to revolutionize the way we manage cardiac health, especially in remote and rural areas with a lack of medical services and equipment.

RESEARCH METHOD OF IOT-BASED ECG MONITORING SYSTEM

The IoT-based ECG monitoring system works by implementing embedded devices, sensors, and cloud technology. Firstly, embedded devices were implanted in the patient's chest. These devices are equipped with Arduino Mega 2560 sensors that capture various ECG data. The captured ECG data is then sent to the cloud server using a Wi-Fi module ESP8266 without any interruption. The captured ECG data is stored in a non-relational database that enables improvements in data storage velocity and versatility, ensuring that data is reliable and accurate.

The cloud server utilizes the hypertext transfer protocol (HTTP) and message queuing telemetry transport (MQTT) servers to provide consumers with rapid and simple ECG data retrieval. Medical professionals can evaluate the cardiac problems of the patients using the web-based application. The application utilizes the captured ECG data acquired by sensors. This IoT-based ECG monitoring system provides an effective and reliable way of predicting, controlling, and monitoring heart disease.

In conclusion, the proposed IoT-based ECG monitoring system is a significant breakthrough in the healthcare sector. The system ensures a consistent and reliable management of patients with chronic diseases, the elderly, and persons that need consistent management. This system guarantees that the obtained data is effective, reliable, and accurate, making it an innovative solution to real-world challenges.

Figure 1 illustrates the entire system and the following steps describe the procedure.

1) Step 1: Read heart data from the human chest by ECG sensor Ad8232.

2) Step 2: Data temporary save to Arduino Mega 2560 and sent it Wi-Fi module microcontroller ESP8266.

3) Step 3: Microcontroller uploads data to IoT cloud using HTTP and MQTT servers. Int J Elec & Comp Eng ISSN: 2088-8708 ρ Internet of things based electrocardiogram monitoring system using … (Md. Obaidur Rahman) 3741

4) Step 4: Dataset reports are uploaded to the prediction stage for pre-processing.

− Handle null values: Possible values are {0 or 'index', 1 or 'columns'}, default 0. If 0, drop rows with null values. If 1, drop columns with missing values.

− Converting Data Type: From dataset number and age attribute are converted to integer, and P, Q, R, S, and T are converted to float data type.

5) Step 5: Apply correlation and covariance to identify which attributes are behind heart condition in (1) and (2).

6) Step 6: Apply linear regression algorithm to predict heart disease using (3) and (4).

7) Step 7: Predicted result sent to application interface to monitor and analyze the heart condition of the patient.

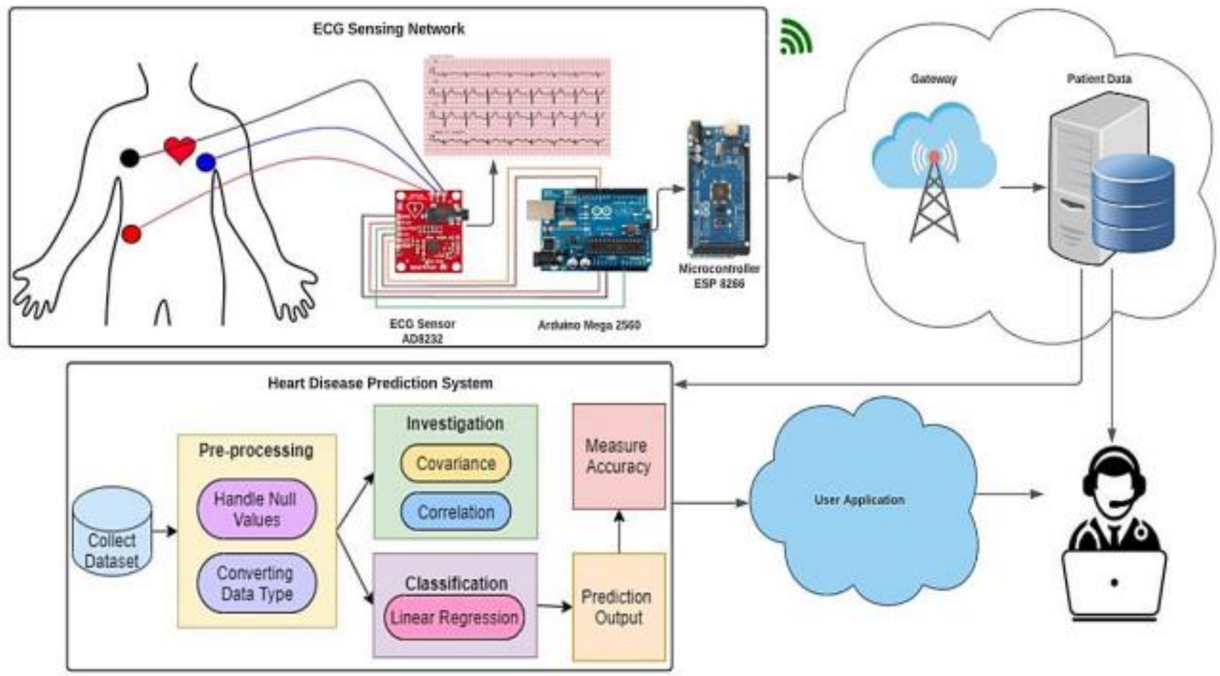

Figure 1. Proposed framework of smart IoT-based ECG monitoring system

ECG sensing network

the ECG sensing network plays a critical role in the device's ability to accurately monitor a user's heart health. By utilizing wearable sensors and advanced signal processing algorithms, the device can provide users with real-time data on their heart's electrical activity. This information can be invaluable in identifying potential cardiac problems, allowing individuals to seek medical attention before serious complications arise. Additionally, the integration of wireless communication technologies enables data to be quickly and easily transmitted to healthcare providers or other professionals who can use it for further analysis or treatment planning. Overall, the ECG sensing network is a key component in the development of advanced monitoring devices that can help individuals stay on top of their heart health and make informed decisions about their well-being.

. **Internet-of-things (IoT) cloud**

The ECG data collected by the sensors is sent to an IoT cloud through a Wi-Fi module (ESP8266). The Wi-Fi module facilitates the transmission of data to the cloud, which can be verified by logging in to the server from a laptop or tablet after submitting the data. The ECG count is used to verify the ECG levels of people over the age of 50. If the ECG count is less than 50, then the data is transmitted to the MQTT web server, which displays the ECG output. If the data is greater than 80 or less than 80, it shows an error. The data is uploaded after the transformation of analog data to digital data using the functional loop process.

To load the MQTT server, the ESP8266 Wi-Fi module is attached to the Arduino board. Once the main program code is uploaded and all the required connections are established, the sensor information is transmitted to the server, which displays the outcomes on the MQTT box in real-time. A web page front-end interface is used for the MQTT box.

The ECG monitoring system can be accessed using various platforms, including Linux, Mac, Web, and Windows. The cyber-level is the primary knowledge center used in this ISM database. Information is gathered from various sources and assembled to build cyberspace. In cases where there is too much data, a specialized analyst is brought in to collect additional information that helps to clarify the status of each patient's ECG records monitor.

The IoT sensor data have been presented in Figure 3(c).

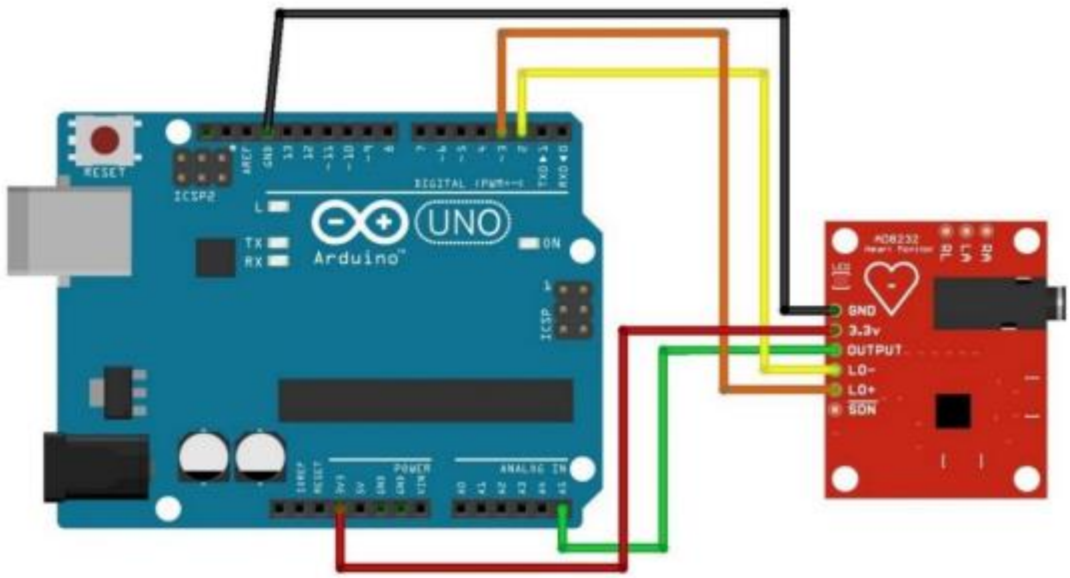

Figure 2. Circuit diagram of AD8232 and Arduino Mega 2560

GUI for ECG monitoring

Both types of GUIs will display real-time ECG data in the form of graphs and charts. Users will be able to set alarms and alerts for certain thresholds and receive notifications through the GUI. The GUI will also allow users to set up and manage their IoT devices, such as adding new sensors or changing settings.

For maintenance, the GUI will provide access to analytics and diagnostic tools to monitor the performance of IoT devices and detect any issues. Users will also be able to view historical ECG data to track progress and identify patterns.

Data acquisition and analysis

The linear regression model is used to predict the heart condition based on the values of P, Q, R, S, and T. The model calculates a line of best fit that minimizes the difference between the predicted and actual values. The slope and inception are calculated using equations (3) and (4) respectively. The linear regression model is trained on the pre-processed dataset and evaluated using metrics such as mean squared error, mean absolute error, and R-squared. The model with the lowest error and highest R-squared value is considered the best model for predicting heart conditions based on ECG signals.

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Figure 3. ECG data load to (a) MQTTBox, (b) data stored in cloud server, and (c) health condition measured by sensor data

USED COMPONENTS

Table 1: Hardware Components and Prices

| Hardware Components | Price (USD) |

Arduino Mega ATmega2560	$16.99
ESP8266 Wi-Fi Module	$5.99
Jumper Cables	$6.99
ECG AD8232	$8.99
Breadboard	$3.99
Output/End Device (Laptop/	$300-$1000
Desktop)	

The total cost of the hardware components required to develop the smart automated ECG monitoring system is approximately $342-$1362 depending on the end device used. The proposed system is affordable and can be used in ruler areas to provide ECG monitoring services to people who live in remote areas where healthcare facilities are scarce.

Table 1. Expense estimate of the hardware components

Hardware elements	Price per unit
Arduino board Mega 2560	820
Heart rate monitor ECG Sensor (AD8232)	1200
Hiletgo CP2102 USB 2.0 Module serial Converter Adapter	170
ESP8266 ESP-01 Wifi Module (AI Cloud Inside)	175
Jumper Wires (Male-Female)	110
400 Tie Points Interlocking Solderless Breadboard	120
Total Amount	2595

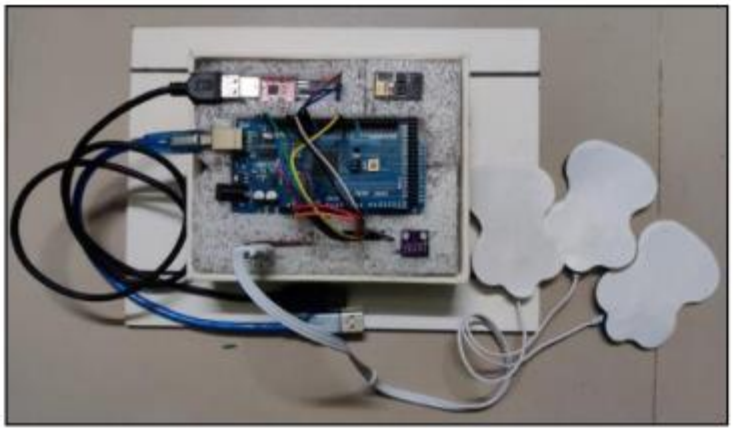

Figure 4. Entire project implementation set

RESULT AND PREDICTION

Additionally, the dataset also shows that individuals with high blood pressure have a higher risk of heart disease. Figure 11 demonstrates the relationship between blood pressure and heart disease risk.

Overall, the proposed system utilizes various techniques such as pre-processing, correlation analysis, and data visualization to accurately identify potential risk factors for cardiovascular disease. By analyzing these risk factors, the system can provide early detection and prevention for individuals at risk of heart disease.

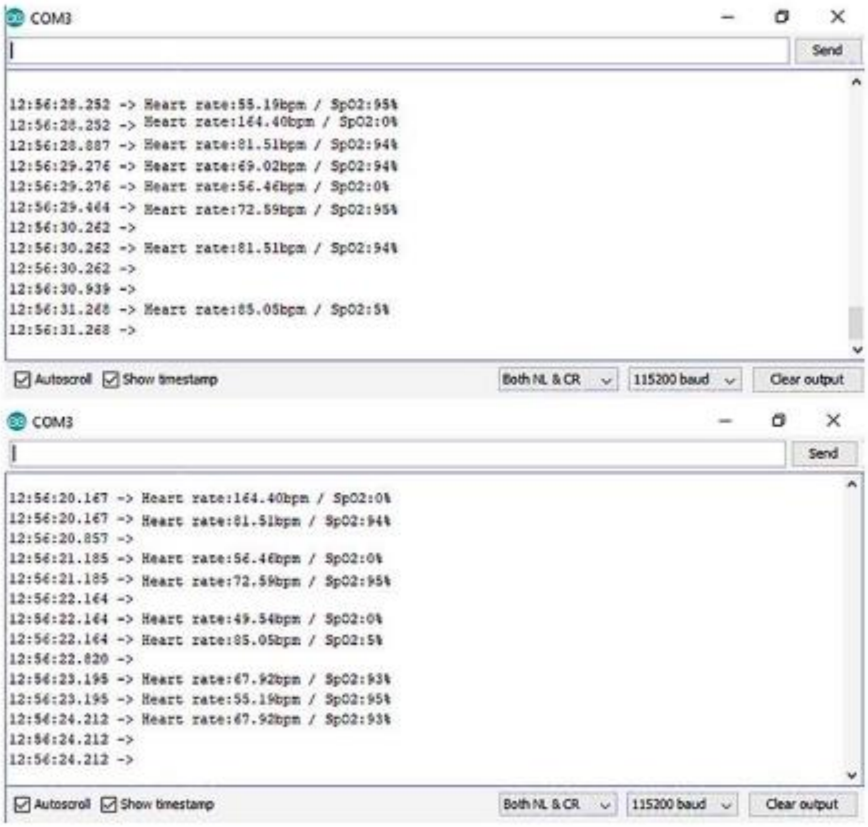

Figure 5. Heartbeat sensor result inspection

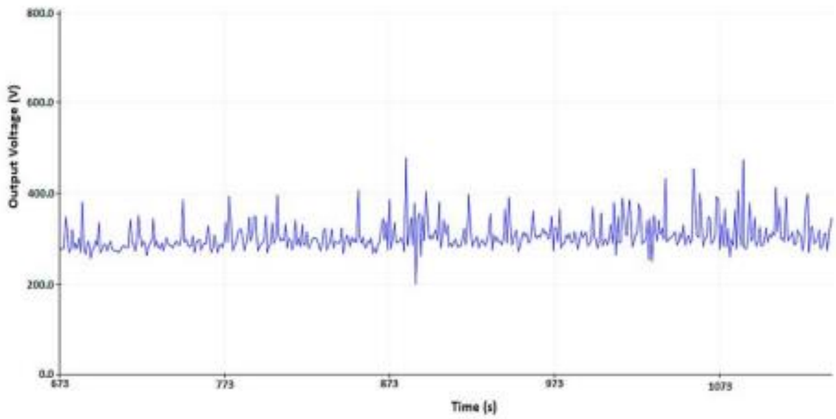

Figure 6. Arduino com port result

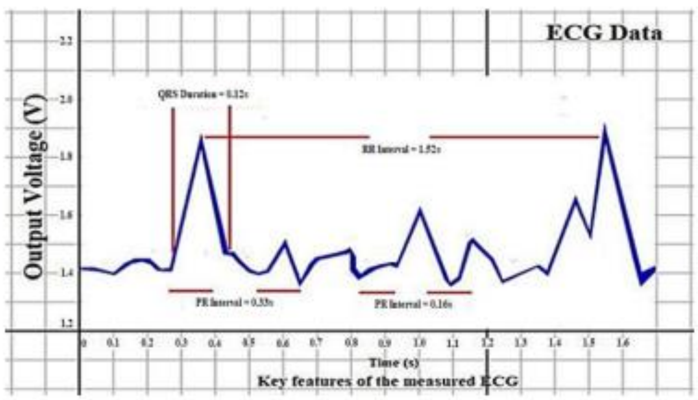

Figure 7. Key features of the ECG measurement

Table 2. Dataset parameters

Column	Null value presence	Data Type
Record No	No null	int64
Age	No null	int64
P	No null	float64
Q	No null	float64
R	No null	float64
S	No null	float64
T	No null	float64

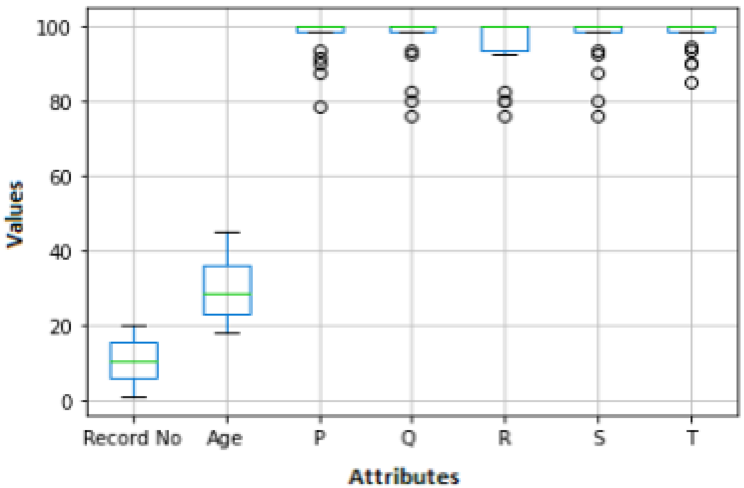

Figure 8. BOX plot of dataset

Table 3. Variable of covariance

	R. N	Age	P	Q	R	S	T
R. N.	34.9999	22.9527	5.9496	3.1419	9.3033	2.0927	6.9999
Age	2.8968	79.0154	23.0283	11.2086	20.9727	9.3649	3.8056
P	5.9157	23.1106	35.3116	-8.3645	9.9382	-9.0118	5.1673
Q	3.1160	11.2698	-8.2879	56.1017	52.8324	54.6937	14.8088
R	9.0139	20.9800	9.9900	52.8920	68.9900	50.2378	12.9169
S	2.4152	9.0671	-9.2035	54.0977	50.3761	50.9416	15.8902
T	6.8524	3.9089	5.4860	14.4958	12.8981	15.8530	19.7410

Table 4. Variables of correlation

	R. N	Age	P	Q	R	S	T
R. N.	1.0000	0.4431	0.1777	0.0657	0.1772	0.0408	0.2775
Age	0.4431	1.0000	0.4338	0.1623	0.2878	0.1383	0.1095
P	0.1777	0.4338	1.0000	-0.2135	0.2052	-0.2072	0.1713
Q	0.0657	0.1623	-0.2135	1.0000	0.8460	0.9893	0.4546
R	0.1772	0.2878	0.2052	0.8460	1.0000	0.8372	0.3474
S	0.0408	0.1383	-0.2072	0.9893	0.8372	1.0000	0.5011
T	0.2775	0.1095	0.1713	0.4546	0.3474	0.5011	1.0000

The coefficients for the predictor variables S, T, and age indicate how much the response parameter

is expected to change for every unit increase in their respective variables. The coefficient for S suggests that

for every one-unit increase in S, the predicted value of y will increase by 0.970256. The coefficient for T,

on the other hand, suggests that for every one-unit increase in T, the predicted value of y will decrease by

0.180931. Finally, the coefficient for age indicates that for every one-unit increase in age, the predicted

value of y will increase by 0.1707005.

Overall, the results suggest that S has a positive effect on y, while T has a negative effect on y.

Age, on the other hand, has a positive effect on y. These findings can be used to make predictions about

the expected value of y for different combinations of predictor variable values, and can also inform further

research into the relationships between these variables.

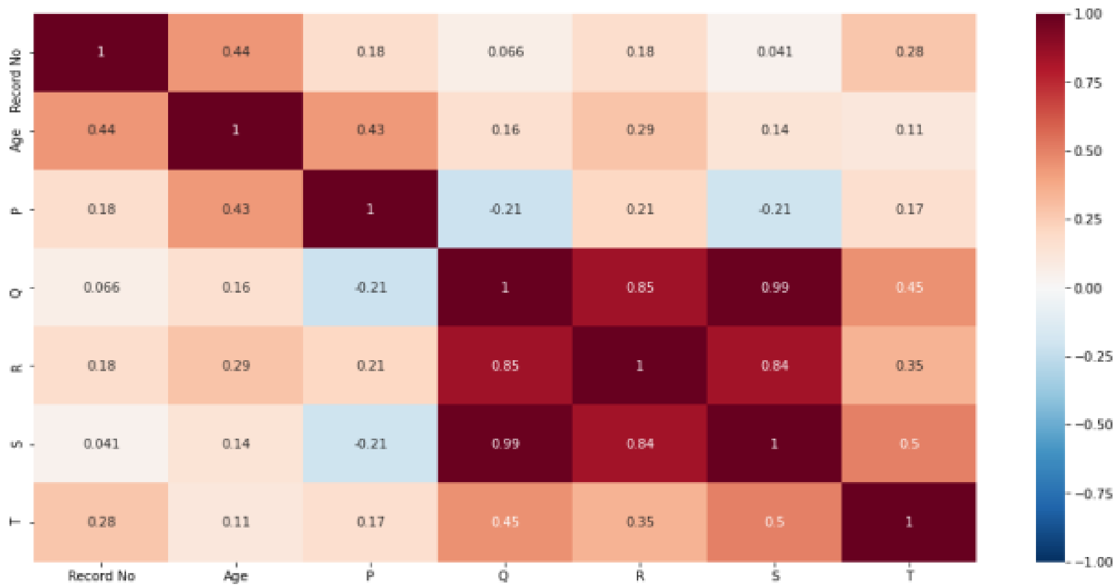

Figure 9. Heat map of correlation among variables

Table 5. Correlation among variables

R	1.0000
Q	0.8460
S	0.8372
T	0.3474
Age	0.2878
P	0.2052

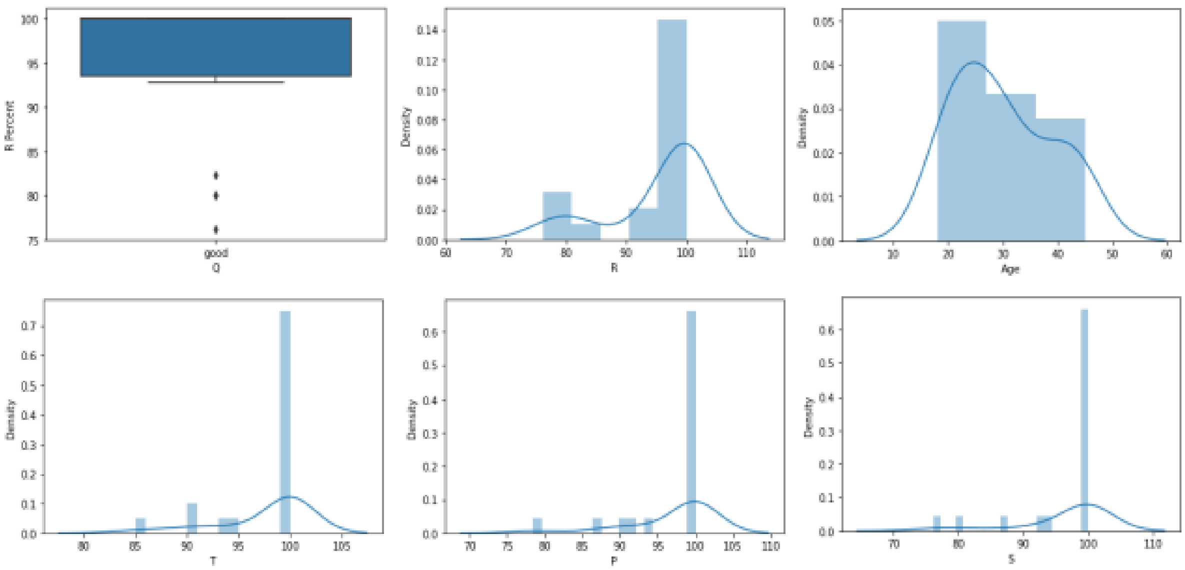

Figure 10. Change of various parameters

Table 6. Prediction of y

Index	Actual	Predicted
2	100	98.10267
5	82.35	84.76861
12	100	98.75442
17	100	100.3838
19	100	97.7768

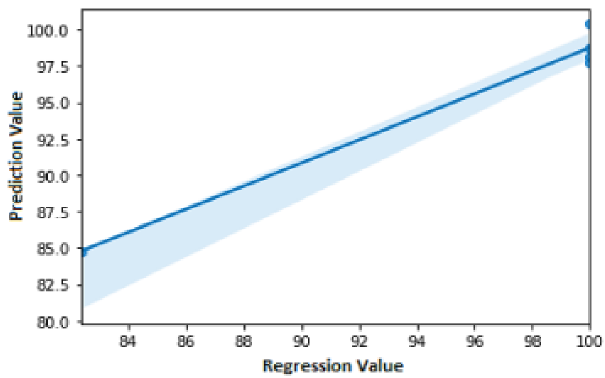

Figure 11. Regression line of prediction

Accuracy measurement

In Figure 12, the bar diagram illustrates the relationship between the actual and predicted plot. The error of prediction for a point is the value of the point minus the predicted value. Analyzing the data, the receive values are,

− Mean absolute error value=1.633702533697678,

− Mean squared error=3.2181888486775514,

− Train set accuracy=68.90878299379251,

− Accuracy percentage=93.5434261396096.

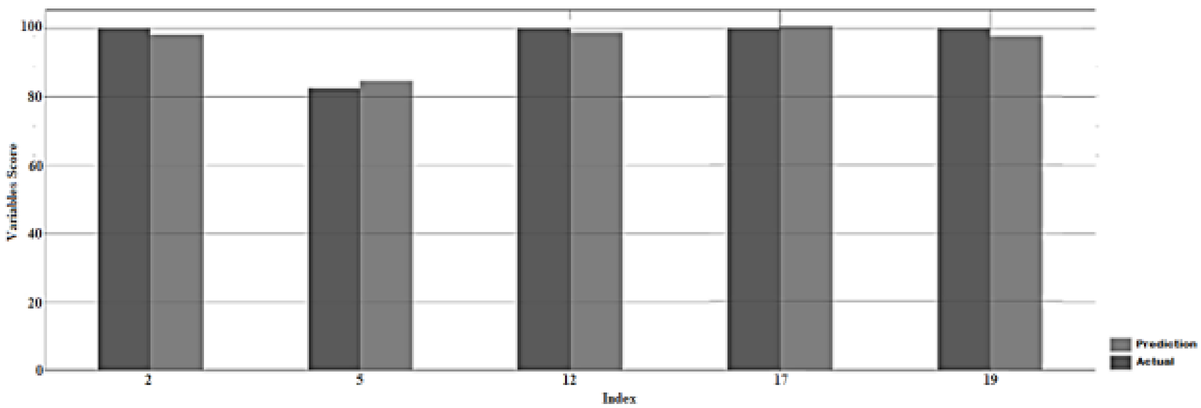

Figure 12. Comparison between actual and predicted data

CONCLUSION

The implementation of IoT-based technologies in healthcare is not only beneficial for patients but also for healthcare providers. The advanced healthcare network can increase efficiency and accuracy in healthcare operations, reduce healthcare costs, and improve the quality of healthcare services. With the integration of IoT-based technologies, healthcare providers can schedule appointments, monitor patients remotely, and provide personalized healthcare services.

However, there are some challenges and problems associated with the implementation of IoT-based healthcare systems, including data security and privacy, interoperability issues, and the requirement for high-speed and reliable internet connectivity. These challenges should be addressed to ensure the successful implementation of IoT-based healthcare systems.

In conclusion, the IoT-based healthcare network has the potential to revolutionize the healthcare industry by providing advanced healthcare services to patients. The integration of smart sensors and advanced technologies can enable continuous health monitoring, personalized healthcare services, and real-time communication between patients and healthcare providers. The future work of this study should focus on adding more parameters and testing various machine learning algorithms to improve the accuracy and efficiency of the system in detecting and diagnosing heart diseases.