International Journal of Electrical and Computer Engineering (IJECE)
Vol. 12, No. 4, August 2022, pp. 3739~3751
ISSN: 2088-8708, DOI: 10.11591/ijece.v12i4.pp3739-3751

Internet of things based electrocardiogram monitoring system using machine learning algorithm

Md. Obaidur Rahman[1], F. M. Javed Mehedi Shamrat[2], Mohammod Abul Kashem[1], Most. Fahmida Akter[3], Sovon Chakraborty[4], Marzia Ahmed[2], Shobnom Mustary[1]
[1]Department of Computer Science and Engineering, Dhaka University of Engineering and Technology, Gazipur, Bangladesh
[2]Department of Software Engineering, Daffodil International University, Dhaka, Bangladesh
[3]Department of Computer Science and Engineering, Bangladesh University of Professionals, Dhaka, Bangladesh
[4]Department of Computer Science and Engineering, European University of Bangladesh, Dhaka, Bangladesh

Article Info

Article history:

Received Jun 29, 2021
Revised Mar 17, 2022
Accepted Mar 30, 2022

Keywords:

Cardiovascular disease
Electrocardiogram monitoring system
Internet of things
Linear regression
Message queuing telemetry transport server

ABSTRACT

In Bangladesh's rural regions, almost 30% of the population lives in poverty. Rural residents also have restricted access to nursing and diagnostic services due to obsolete healthcare infrastructure. Consequently, as cardiac failure occurs, they usually fail to call the services and adopt the facilities. The internet of things (IoT) offers a massive advantage in addressing cardiac problems. This study proposed a smart IoT-based electrocardiogram (ECG) monitoring system for heart patients. The system is divided into several parts: ECG sensing network (data acquisition), IoT cloud (data transmission), result analysis (data prediction) and monetization. P, Q, R, S, and T are ECG signal properties fetched, pre-processed, analyzed and predicted to age level for future health management. ECG data are saved in the cloud and accessible via message queuing telemetry transport (MQTT) and hypertext transfer protocol (HTTP) servers. The linear regression method is utilized to determine the impact of electrocardiogram signal characteristics and error rate. The prediction was made to see how much variation there was in PQRST regularity and its sufficiency to be utilized in an ECG monitoring device. Recognizing the quality parameter values, acceptable outcomes are achieved. The proposed system will diminish future medical costs and difficulties for heart patients.

Corresponding Author:

F. M. Javed Mehedi Shamrat
Department of Software Engineering, Daffodil International University
102/1, Sukrabad, Mirpur Road, Dhaka 1207, Bangladesh
Email: javedmehedicom@gmail.com

1. INTRODUCTION

According to the Bangladesh Bureau of Statistics (BBS), a total of 854,253 people died for various reasons in 2020, and about 21.1% died of heart disease. According to the BBS report, almost 1,80,408 people have died of cardiac attacks [1]. Patients with heart diseases usually remain at home and seek medical attention only when they become sick. However, they would not usually feel sick until the very late stage of the illness and the harm has been permanent already. And most people suffer before any medication is received. The solution to improving the efficiency of cardiac disorders and that the mortality rate is therefore to make the mode of passive healthcare a general one. This requires doctors to track patients' physical condition and determine whether they can provide healthcare depending on the status of patients. Researchers and experts have made massive advancements in the area of medical and health care systems over the last few decades.

Reduced cellular connectivity costs and the introduction of many health surveillance technologies into standard devices such as smartphones have also aided in addressing such problems as a lack of medical services and equipment [2], [3]. The use of internet of things (IoT) technology in the early identification of cardiac problems via electrocardiogram (ECG) monitoring has shown promise. In the past, IoT has been used in ECG monitoring in several types of research [4]–[7].

The IoT has expanded human freedom while also increasing its ability to connect with the outside world. The IoT has become a major contributor to global communication with the help of future protocols and algorithms. The IoT definition can be extended to various fields such as smart health care, smart agriculture, forecasts on environmental impacts, smart power grids, smart electric vehicles, and smart connections between various physical components [8]–[10]. The World Health Organization (WHO) [11] states that ambiguity about someone's health is a frequent issue among the elderly. Older individuals, particularly elderly cardiovascular patients, need to check their health problems regularly. Present cardiovascular diagnostic methods must be upgraded, including the use of contemporary technologies, to identify heart conditions in a timely and accurate way at a cheap cost [12]–[14]. ECG screening is widely utilized in hospitals and health research institutes in rural areas due to heart-related health problems [15]. cyber-physical systems (CPS), instead of the IoT, can be thought of as information technologies. CPS is an IoT-based process that integrates new features to facilitate communication, computing, and control [16]. It adds to a sophisticated intelligence system that impacts daily activity significantly [17]. Micro electro mechanical systems may be used to activate the CPS idea for networking in the form of monitoring, computing, and controlling the physical environment. This project aims to create a portable cardiac monitoring device using ECG technology [18]. The ECG monitoring technique has been utilized to identify ECG signals utilizing unintrusive sensors, and the data acquired from the sensors were transmitted to the smartphone using Wi-Fi communication protocols such as Bluetooth or Zigbee [19]. The IoT-based framework addresses the problem of time waste in ambulatory services and hospitals by requiring data to be sent through a global system for mobile communication (GSM) module connected via Bluetooth technology. The primary emphasis is on routine health checks and monitoring various bodily characteristics with the aid of various sensors connected to the body [20]. Experiments have shown that heart illness may be treated, managed, and avoided by using ECG signals in a continuous data monitoring method [21].

Furthermore, the patient's measured ECG report generated from this intelligent smart information system may be readily transmitted through text messages, online servers, and other mobile apps. Nurses and patient families may utilize the webserver's real-time monitoring feature in disaster situations. Rural area peoples may utilize this method at a low cost.

2. RESEARCH METHOD OF IOT-BASED ECG MONITORING SYSTEM

The IoT and wearable monitoring technologies are emerging technologies that are expected to provide a wide variety of uses in healthcare [22]. The healthcare sector was fast to adopt the IoT [23], as incorporating IoT features into medical equipment improves service consistency and reliability. This has significant benefits for the elderly, patients with chronic diseases, and persons that need consistent management [24]. IoT-based healthcare systems are used to collect critical data, such as real-time adjustments in health parameters and notifications in medical parameter intensity within a regular time frame, resulting in massive volumes of health data being generated by IoT devices. The IoT is widely regarded as the most important potential technology, and the healthcare industry is paying close attention to it.

This study proposed and developed an embedded IoT system [25] for controlling, monitoring, and predicting heart disease. The devices were implanted in the patient's chest and used Arduino Mega 2560 sensors to obtain various ECG data, which were then sent to the cloud server (through a Wi-Fi module ESP8266) without interruption. The hypertext transfer protocol (HTTP) and message queuing telemetry transport (MQTT) servers are all deployed in the cloud environment to give consumers rapid and simple ECG data retrieval. The collected information is processed in a non-relational database, allowing for improvements in data storage velocity and versatility [26]. A web based application is designed and developed for the medical professionals to evaluate the cardiac problems of the patients using ECG data acquired by sensors. Throughout this study, the suggested IoT-based cloud technologies guarantee that the obtained data is effective, reliable, and accurate. The entire proposed IoT-based ECG monitoring system is depicted in Figure 1. Creating this proposed system will be aided by a proper application of the suggested model, facilitating working with real-world challenges. This section shows how the process works. 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.

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.

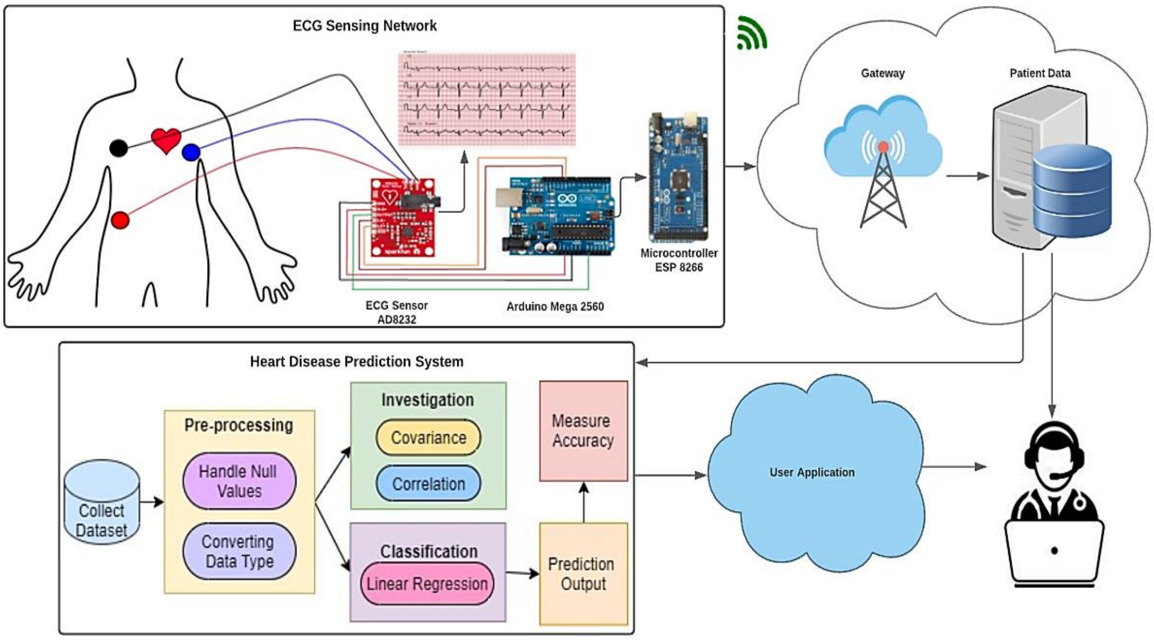


Figure 1. Proposed framework of smart IoT-based ECG monitoring system

2.1. ECG sensing network

The ECG sensing network serves as the backbone of the whole device, gathering physiological data from the body surface and sending it to the IoT cloud through a wireless channel. In this device, wearable ECG sensors are usually used, not affecting the user's everyday life [27]. ECG data may be recorded for hours or even days using this method. Analog device AD8232 ECG module is used with the AD8232 IC, which is a single-chip built to extract, amplify, and process biopotential signals for biopotential measurement applications. The AD8232 is a small chip used to calculate cardiac electrical activity. An ECG, or electrocardiogram, may track this electrical behavior. Electrocardiography is a test that may be used to detect various cardiac problems. First, three-electrode pads are implanted in the body, collecting data. Since the characters are so large, the ECG result is first shown on the Arduino com port screen. For this case, the data is sent through the Wi-Fi module and displays the ECG curve on the web page and the mobile APP. ECG sensor will directly connect to Arduino Mega 2560 (built Wi-Fi). ECG AD8232 sensor and Arduino Mega 2560 pin ground to ground (GND to GND), 3.3v to 3.3v, OUTPUT to A0, LO- to 11, LO+ to 10 have been integrated. ECG sensor must be placed human chest to read and measure the heart's electrical activity. Figure 2 illustrated the circuit diagram of AD8232 and Arduino Mega 2560 pin connection.

2.2. Internet-of-things (IoT) cloud

The ECG data collected by sensors is sent to the IoT cloud through a Wi-Fi module (ESP8266). The Wi-Fi module aids in the transmission of data to the cloud. Anyone will verify the performance 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. Measure the ECG data and transmit information to the cloud (analog or digital) if the quantity is fewer than 50, then the data is transmitted to the MQTT web server, which shows the ECG output. If the data is greater than 80, the ECG is less than 80, and the ERROR is shown. The uploaded procedure is complete (data is up) and transforms analog data to digital data using the functional loop process. The sensor ESP8266 (Wi-Fi module) has been attached to the Arduino board for loading the MQTT server [28]. To do this, link the sensor ESP8266 GPI 03 pin to GND. The RX, TX and GPIO 0 pins must be disconnected after transferring the program. Secondly, established the connection between the ESP8266 Wi-Fi module and Arduino [29]–[31]. The RX pin of ESP8266 will be connected to TX pin 8 of Arduino and The TX pin of ESP8266 will be connected to RX pin 9 of Arduino which is defined in the code. Then upload the main program code of this project. Once completed all of these steps, the system will execute and transmit the sensor information to the server, which will display the outcomes on the MQTT box. It shows the real-time value of the website. We utilized a web page front-end interface throughout the MQTT box, as seen in Figure 3.

In addition to Linux, Mac, Web, and Windows, MQTT Box for ECG monitoring system is also available is shown in Figures 3(a) and 3(b). The cyber-level is the leading knowledge center of this ISM database [32]. To build cyberspace, information is gathered from many resources and assembled. When there is too much data, a specialized analyst is called in to collect extra 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).

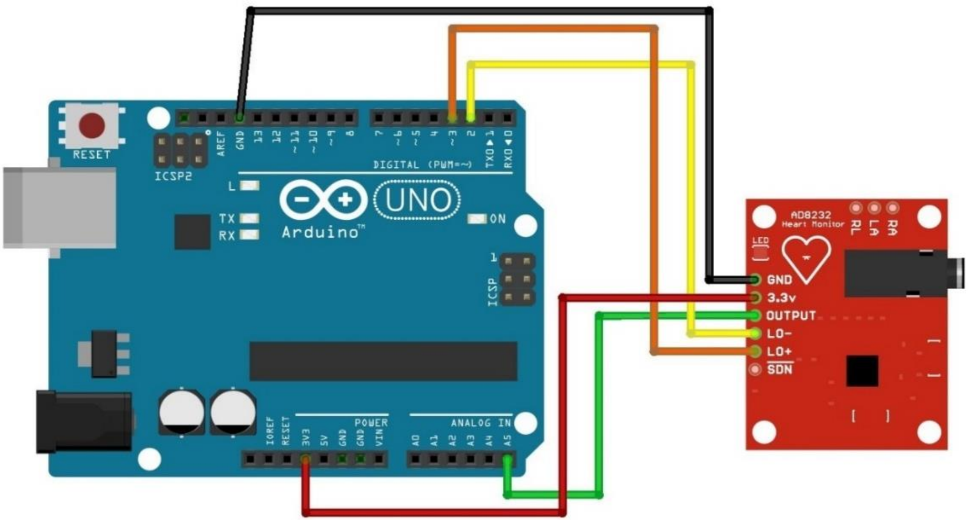


Figure 2. Circuit diagram of AD8232 and Arduino Mega 2560

2.3. GUI for ECG monitoring

The GUI handles data visualization and maintenance. It allows quick access to data stored in the IoT cloud. Users will use real-time visualizations of ECG data by logging into the cloud [24]. For users to visualize ECG info, two types of GUIs are available: mobile and websites. A mobile device may react quickly to user feedback, while webpages are easier to maintain and update.

2.4. Data acquisition and analysis

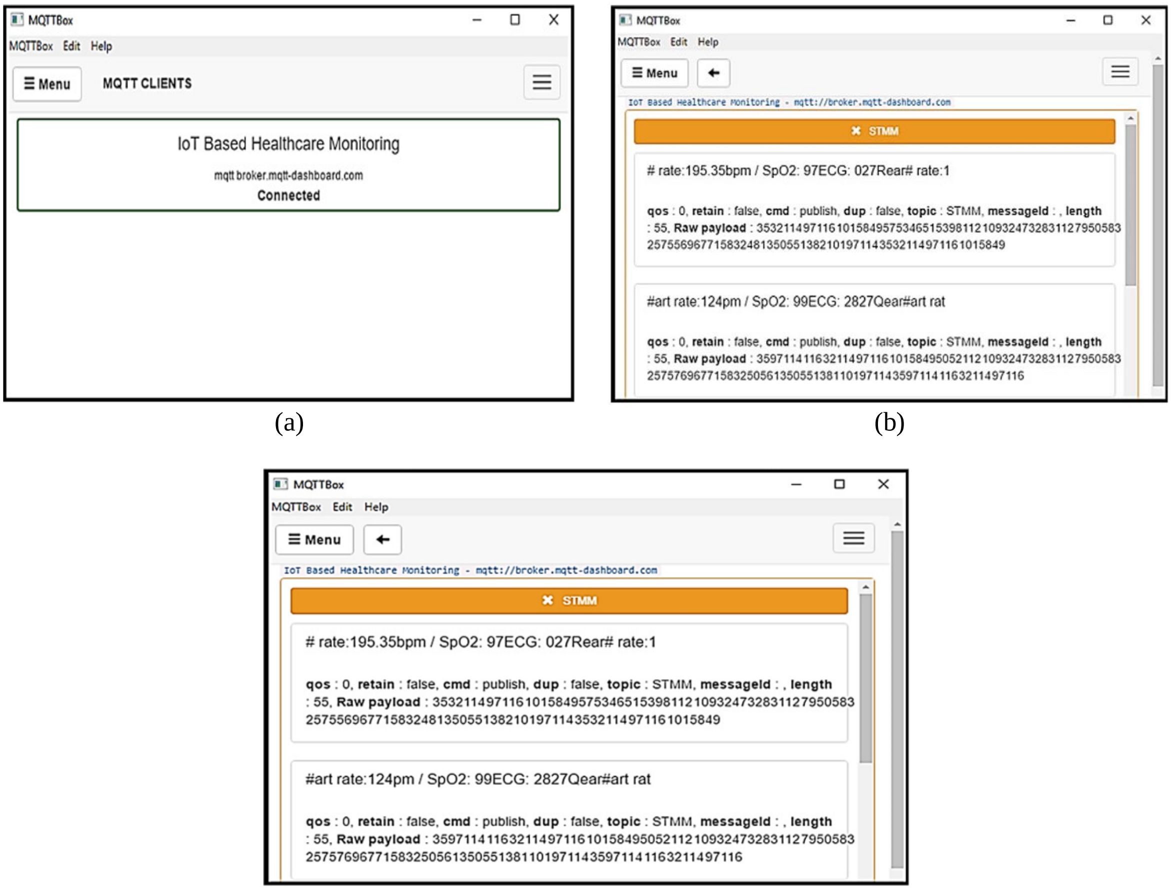
2.4.1. Data collection

The dataset used to train and test the machine learning models are collected from 2,000 volunteers. The dataset contains data from ECG signals. The dataset includes attributes such as Record No, age of the patient, P, Q, R, S, T, and angina information.

2.4.2. Data pre-processing

Before the dataset can be used to train and test the machine learning models, the raw data must be pre-processed [33]. To get a clean dataset, the pre-processing steps taken in this study are,

- Handling missing data: with the presence of missing data in the dataset, the prediction accuracy of the machine learning model suffers. So missing data in the dataset build for the paper is handled so that there is no null cell in the dataset.
- Converting data type: for a consistent result, the record number attribute and the age attribute are converted to integer type whereas P, Q, R, S, and T are converted to float data type.



(a) (b) (c)

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

2.4.3. Investigating the correlation and covariance

Correlation determines to what degree the attributes of the dataset coordinate with others. And covariance is the measure to determine the relationship between two random attributes. To identify which attributes are behind heart condition using correlation and covariance, the (1) and (2) are used respectively.

$$r = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum(x_i-\bar{x})^2 \sum(y_i-\bar{y})^2}} \quad (1)$$

$$cov_{x,y} = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{N-1} \quad (2)$$

Where, r is correlation coefficient, $cov_{x,y}$ is covariance between x and y, x_i is value of x variable from the dataset, y_i is value of y variable from the dataset, $\bar{x}$ is meanof x_i, $\bar{y}$ is mean of y_i, and N is number of data in the dataset.

2.4.4. Classification (linear regression)

The ECG attributes P, Q, R, S, and T are utilized to identify heart disease using the linear regression method. The approach uses the regression model to create a solid path that reduces the variance among present and final value. The optimum suit lines for the n points (S1, T1), (S2, T2),......, (Sn, Tn) are of the type $y=mx+b$. To calculate the slope and inception, the (3) and (4) are used, respectively.

$$Slope = m = \frac{n(\sum xy) - (\sum xy)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad (3)$$

$$Intercept = b = \frac{\sum y - m(\sum x)}{n} \quad (4)$$

The score of one variable is anticipated depending on the results of another. The variable to be predicted is the criterion parameter, abbreviated as *y*. The predictor variable, known as *x*, is the variable on which the predictions are based.

3. USED COMPONENTS

To develop this smart automated system the following hardware component is used. Here the components are presented with each price in Table 1. This study proposed an inexpensive ECG monitoring system for people in ruler areas, but anyone can adopt the system. Components required: Arduino Mega ATmega2560, ESP8266 Wi-Fi module, jumper cables, ECG AD8232, breadboard, output/end device (laptop/desktop). The proposed framework has been formed and constructed by assembling all of the components together. The implementation architecture is shown in Figure 4.

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

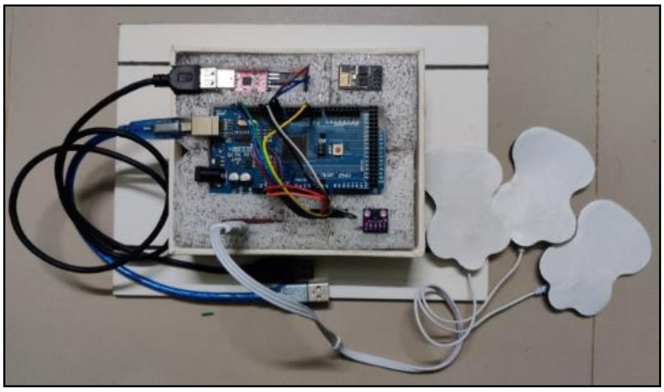


Figure 4. Entire project implementation set

4. RESULT AND PREDICTION

The heartbeat result is compared to the heartbeat output of an automated existing pressure measurement system to determine if the pulse tracker is working. The information was gathered from five individuals of varying ages. Figure 5 depicts the information for a particular day and time. The ECG reading is generated by activating the ECG sensor by placing the three electrodes on the sufferer's thorax. Figure 6 presents the ECG results: Arduino com port result and the distinguishing characteristic of the recorded ECG data is depicted in Figure 7.

The dataset used for the proposed system goes through the pre-processing stage to ensure a clean dataset for highly accurate analysis. The outcome of the preprocessed dataset is depicted in Table 2. The box plot of all the attributes containing outliers or extreme values in the dataset is shown in Figure 8.

Correlation and covariance among the variables show which attributes are more responsible for heart disease. Tables 3 and 4 show the covariance and correlation of the dataset, respectively. Figure 9 illustrates the correlation in the form of a heat map.

Analyzing the heat map shows that Q, S, T, and P have moderate correlation whereas R and Q have a robust optimistic relationship. The sorted correlation among variables with R is listed in Table 5. The 'Q' variety is a significant risk indicator for cardiovascular problems because most 'R' patients experience heart palpitation and the variable rise level is more between 120-150 among the age range of 40-60. Figure 10 represents various parameters. It has been found that individuals with cardiovascular illness have either very hypertension or extremely high cholesterol levels.

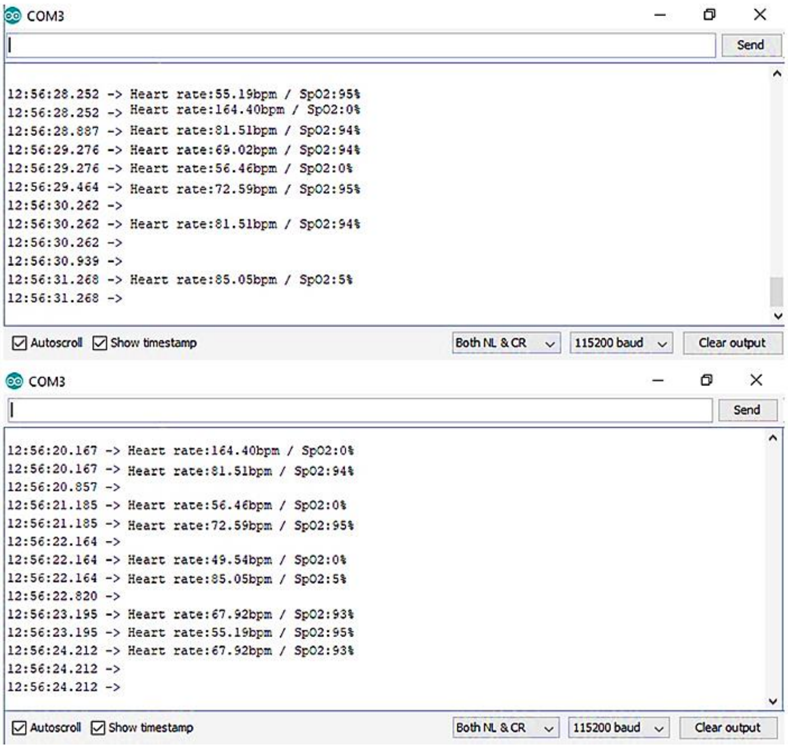


Figure 5. Heartbeat sensor result inspection

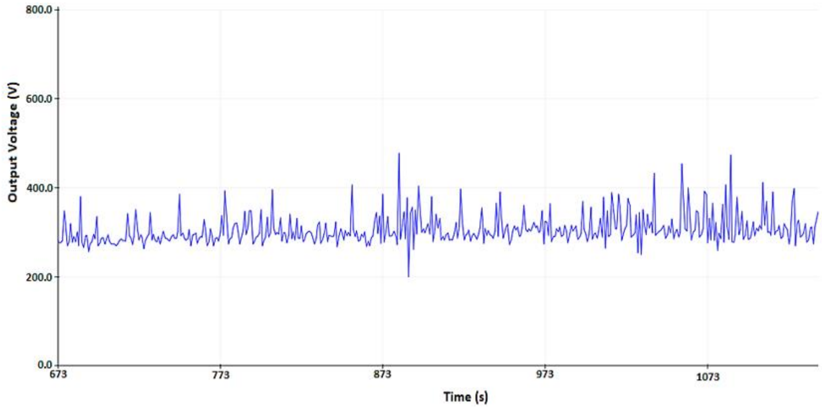


Figure 6. Arduino com port result

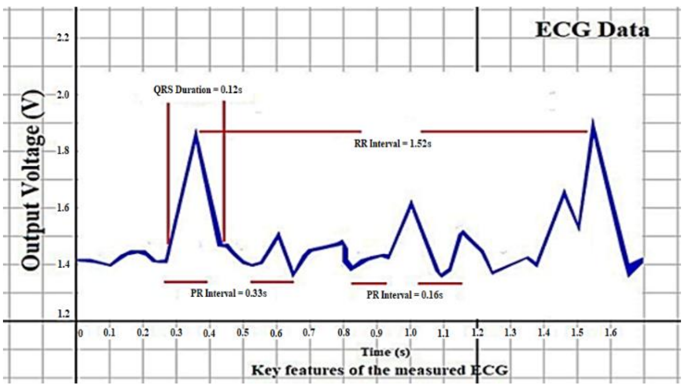


Figure 7. Key features of the ECG measurement

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

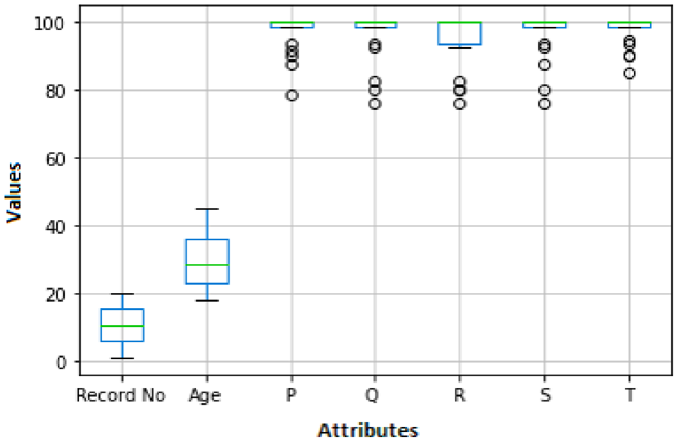


Figure 8. BOX plot of dataset

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 connection between a predictor variable and the responder is determined using a linear regression model to estimate unknown population characteristics: i) the value of interception is determined 14.319164821638992, ii) the value of the coefficient for S is 0.970256. iii) the value of the coefficient for T is -0.180931, and iv) the value of the coefficient for age is 0.1707005.

If an optimistic symbol indicates that the response parameter will likewise grow as the predictor variable increases, while a pessimistic symbol indicates that the parameter of response will decrease as the predictor variable expands. The research utilizes simple regression since just one variable is y. When Y is shown as the function of x, the predictions form a direct line. Table 6 shows the sample of the predicted values.

The data are plotted in Figure 11 and indicate the positive relation between x and y. The regression line consists of the predicted score on y for each possible value of x. This specifies that the higher the value of x, the higher the prediction value of y.

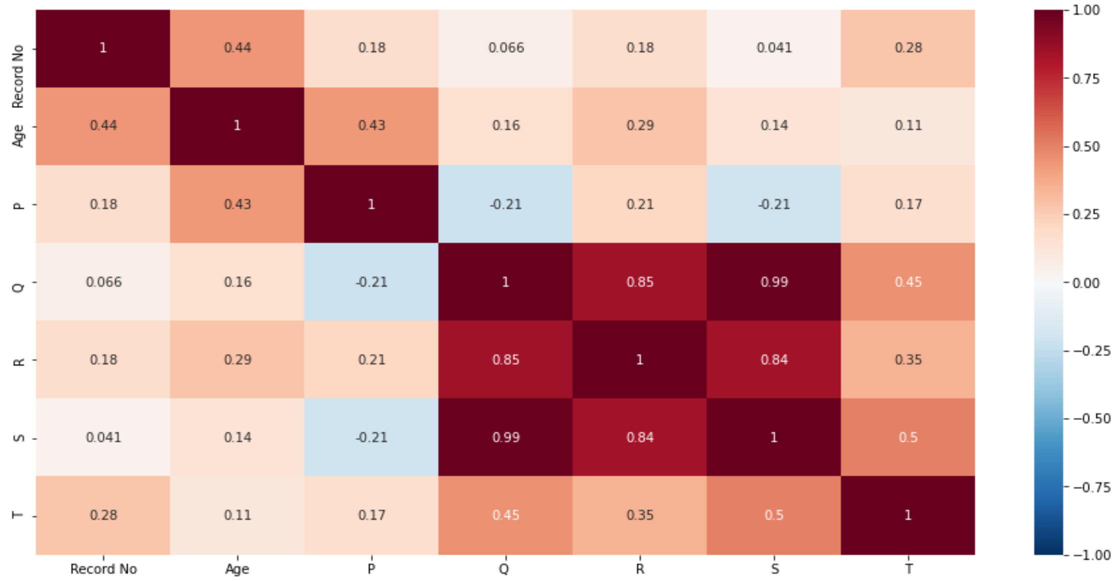


Figure 9. Heat map of correlation among variables

Table 5. Correlation among variables

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

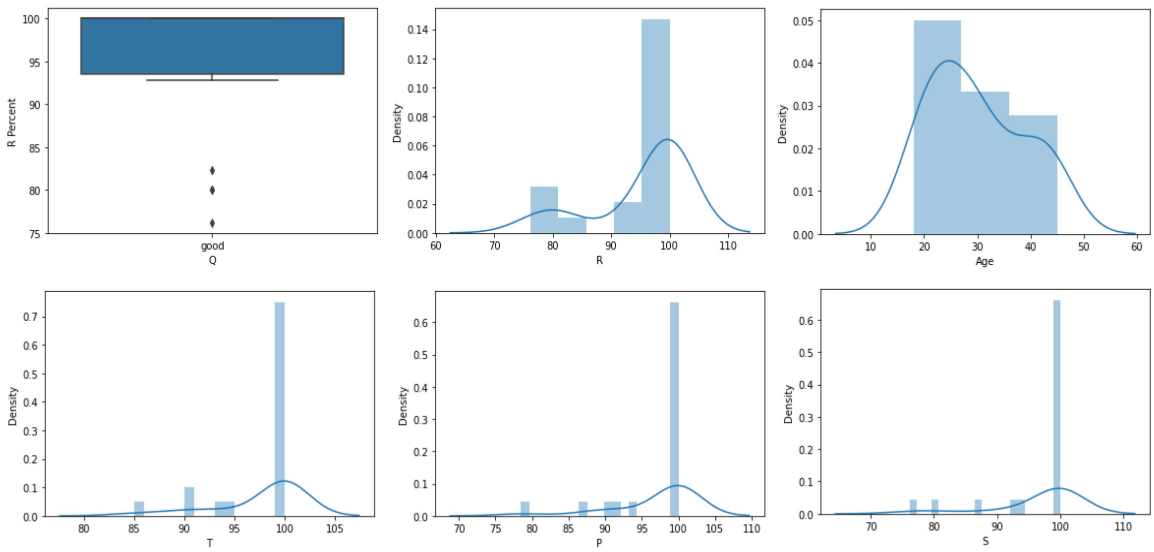


Figure 10. Change of various parameters

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

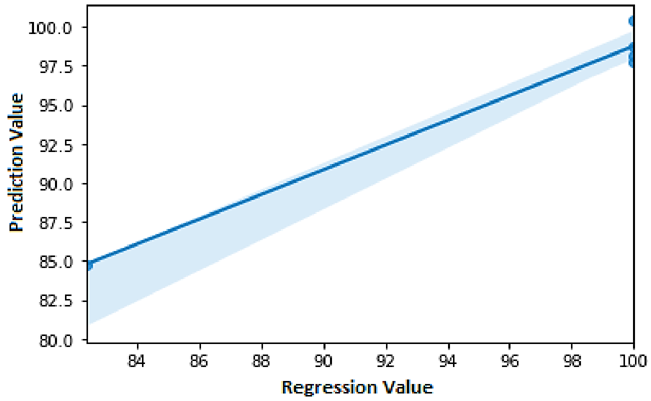


Figure 11. Regression line of prediction

4.1. 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.

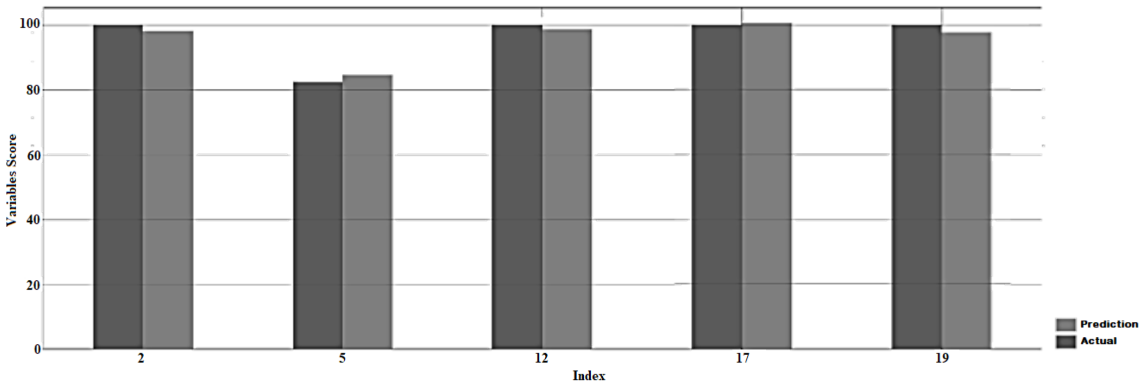


Figure 12. Comparison between actual and predicted data

5. CONCLUSION

In general, an IoT-based healthcare network attaches to intelligent smart sensors connected to the human body for everyday healthiness tracking. This paper discussed the IoT based on patient management systems. At the moment, also discussed the advantages, problems, and possibilities associated with system technologies utilized for smartphones or devices. Continuous remote surveillance is needed due to the necessity of observing the medical patient. Part of the technological work in this paper is to provide continuous patient supervision through the site and app service and a live monitor and phone texting service. This study has linked the initial medical method to advanced healthcare applications. The present time represents a period of reduced healthcare costs, especially for people living in rural areas. We will add some parameters like RR, PR, QRS-complex, QRS-interval, QT, and QRST in future work. So that, the system can find out the heart disease very easily. Those parameters will be checked in various ML algorithms.

REFERENCES

[1] A. K. M. M. Islam, A. K. M. Mohibullah, and T. Paul, "Cardiovascular disease in Bangladesh: a review," *Bangladesh Heart Journal*, vol. 31, no. 2. pp. 80–99, Apr. 2017., doi: 10.3329/bhj.v31i2.32379.

[2] Z. Ali, M. S. Hossain, G. Muhammad, and A. K. Sangaiah, "An intelligent healthcare system for detection and classification to discriminate vocal fold disorders," *Future Generation Computer Systems*, vol. 85, pp. 19–28, Aug. 2018, doi: 10.1016/j.future.2018.02.021.
[3] W. Ping, W. Jin-gang, S. Xiao-bo, and H. Wei, "The research of telemedicine system based on embedded computer," in *2005 IEEE Engineering in Medicine and Biology 27th Annual Conference*, 2005, pp. 114–117., doi: 10.1109/IEMBS.2005.1616355.
[4] S. K. Y. Donzia, H.-K. Kim, and B. Y. Shin, "Study on cloud computing and emergence of the internet of the thing in industry," in *2018 5th NAFOSTED Conference on Information and Computer Science (NICS)*, Nov. 2018, pp. 334–337, doi: 10.1109/NICS.2018.8606834.
[5] T. Tekeste, H. Saleh, B. Mohammad, and M. Ismail, "Ultra-low power QRS detection and ECG compression architecture for IoT healthcare devices," *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 66, no. 2, pp. 669–679, Feb. 2019, doi: 10.1109/TCSI.2018.2867746.
[6] J. B. Bathilde, Y. L. Then, R. Chameera, F. S. Tay, and D. N. A. Zaidel, "Continuous heart rate monitoring system as an IoT edge device," in *2018 IEEE Sensors Applications Symposium (SAS)*, Mar. 2018, pp. 1–6., doi: 10.1109/SAS.2018.8336777.
[7] B. J. Drew *et al.*, "Practice standards for electrocardiographic monitoring in hospital settings," *Circulation*, vol. 110, no. 17, pp. 2721–2746, Oct. 2004, doi: 10.1161/01.CIR.0000145144.56673.59.
[8] E. Agu *et al.*, "The smartphone as a medical device: Assessing enablers, benefits and challenges," in *2013 IEEE International Workshop of Internet-of-Things Networking and Control (IoT-NC)*, Jun. 2013, pp. 48–52., doi: 10.1109/IoT-NC.2013.6694053.
[9] A. Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of things for smart cities," *IEEE Internet of Things Journal*, vol. 1, no. 1, pp. 22–32, Feb. 2014, doi: 10.1109/JIOT.2014.2306328.
[10] P. Goswami, A. Mukherjee, B. Sarkar, and L. Yang, "Multi-agent-based smart power management for remote health monitoring," *Neural Computing and Applications*, May 2021, doi: 10.1007/s00521-021-06040-4.
[11] WHO, "Ageing," *World Health Organization*. http://www.who.int/topics/ageing/en/ (accessed May 06, 2021).
[12] A. Banerjee and S. K. S. Gupta, "Analysis of smart mobile applications for healthcare under dynamic context changes," *IEEE Transactions on Mobile Computing*, vol. 14, no. 5, pp. 904–919, May 2015, doi: 10.1109/TMC.2014.2334606.
[13] L. Manman, Q. Xin, P. Goswami, A. Mukherjee, and L. Yang, "Energy-efficient dynamic clustering for IoT applications: a neural network approach," in *2020 IEEE Eighth International Conference on Communications and Networking (ComNet)*, Oct. 2020, pp. 1–7., doi: 10.1109/ComNet47917.2020.9306092.
[14] A. Mukherjee, J. J. P. C. Rodrigues, P. Goswami, L. Manman, R. Hazra, and L. Yang, "Green cooperative communication based cognitive radio sensor networks for IoT applications," in *2020 IEEE International Conference on Communications Workshops (ICC Workshops)*, Jun. 2020, pp. 1–6., doi: 10.1109/ICCWorkshops49005.2020.9145290.
[15] Z. Yang, Q. Zhou, L. Lei, K. Zheng, and W. Xiang, "An IoT-cloud based wearable ECG monitoring system for smart healthcare," *Journal of Medical Systems*, vol. 40, no. 12, Dec. 2016, doi: 10.1007/s10916-016-0644-9.
[16] M. Bsoul, H. Minn, and L. Tamil, "Apnea MedAssist: real-time sleep apnea monitor using single-lead ECG," *IEEE Transactions on Information Technology in Biomedicine*, vol. 15, no. 3, pp. 416–427, May 2011, doi: 10.1109/TITB.2010.2087386.
[17] M. F. ul Hassan, D. Lai, and Y. Bu, "Characterization of single lead continuous ECG recording with various dry electrodes," in *Proceedings of the 2019 3rd International Conference on Computational Biology and Bioinformatics-ICCBB '19*, 2019, pp. 76–79., doi: 10.1145/3365966.3365974.
[18] P. Jevon, B. Ewens, and J. S. Pooni, *Monitoring the critically ill patient*, 3rd Editio. Wiley, 2012.
[19] H. Kim *et al.*, "A configurable and low-power mixed signal SoC for portable ECG monitoring applications," *IEEE Transactions on Biomedical Circuits and Systems*, vol. 8, no. 2, pp. 257–267, Apr. 2014, doi: 10.1109/TBCAS.2013.2260159.
[20] N. Gupta, H. Saeed, S. Jha, M. Chahande, and S. Pandey, "IOT based health monitoring systems," in *2017 International Conference on Innovations in Information, Embedded and Communication Systems (ICIIECS)*, Mar. 2017, pp. 1–6., doi: 10.1109/ICIIECS.2017.8276181.
[21] S. P. Preejith, R. Dhinesh, J. Joseph, and M. Sivaprakasam, "Wearable ECG platform for continuous cardiac monitoring," in *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Aug. 2016, pp. 623–626., doi: 10.1109/EMBC.2016.7590779.
[22] G. Manogaran, D. Lopez, C. Thota, K. M. Abbas, S. Pyne, and R. Sundarasekar, "Big data analytics in healthcare internet of things," in *Understanding Complex Systems*, 2017, pp. 263–284., doi: 10.1007/978-3-319-55774-8_10.
[23] L. M. Dang, M. J. Piran, D. Han, K. Min, and H. Moon, "A survey on internet of things and cloud computing for healthcare," *Electronics*, vol. 8, no. 7, Jul. 2019, doi: 10.3390/electronics8070768.
[24] N. Scarpato, A. Pieroni, L. Di Nunzio, and F. Fallucchi, "E-health-IoT universe: a review," *International Journal on Advanced Science, Engineering and Information Technology*, vol. 7, no. 6, Dec. 2017, doi: 10.18517/ijaseit.7.6.4467.
[25] M. R. Islam *et al.*, "Smart parking management system to reduce congestion in urban area," in *2020 2nd International Conference on Electrical, Control and Instrumentation Engineering (ICECIE)*, 2020, pp. 1–6., doi: 10.1109/ICECIE50279.2020.9309546.
[26] M. O. Rahman *et al.*, "Internet of things (IoT) based ECG system for rural health care," *International Journal of Advanced Computer Science and Applications*, vol. 12, no. 6, 2021, doi: 10.14569/IJACSA.2021.0120653.
[27] F. M. J. M. Shamrat, S. M. Allayear, M. F. Alam, M. I. Jabiullah, and R. Ahmed, "A smart embedded system model for the AC automation with temperature prediction," in *Communications in Computer and Information Science*, Springer Singapore, 2019, pp. 343–355., doi: 10.1007/978-981-13-9942-8_33.
[28] Microcontrollerslab, "What is MQTT and how MQTT works?" microcontrollerslab, 2021. https://microcontrollerslab.com/what-is-mqtt-and-how-it-works/ (accessed Dec. 22, 2021)
[29] F. M. J. M. Shamrat, Z. Tasnim, N. I. Nobel, and M. R. Ahmed, "An automated embedded detection and alarm system for preventing accidents of passengers vessel due to overweight," in *Proceedings of the 4th International Conference on Big Data and Internet of Things*, Oct. 2019, pp. 1–5., doi: 10.1145/3372938.3372973.
[30] P. Karmokar *et al.*, "A novel IoT based accident detection and rescue system," in *2020 Third International Conference on Smart Systems and Inventive Technology (ICSSIT)*, Aug. 2020, pp. 322–327., doi: 10.1109/ICSSIT48917.2020.9214296.
[31] F. M. J. M. Shamrat, N. I. Nobel, Z. Tasnim, and R. Ahmed, "Implementation of a smart embedded system for passenger vessel safety," in *Advances in Computational Intelligence, Security and Internet of Things*, Springer Singapore, 2020, pp. 357–370., doi: 10.1007/978-981-15-3666-3_29.
[32] ISM, "Library." ISM. https://www.ism.lt/en/library/ (accessed May 06, 2021).
[33] S. Akter, F. M. J. M. Shamrat, S. Chakraborty, A. Karim, and S. Azam, "COVID-19 detection using deep learning algorithm on chest x-ray images," *Biology*, vol. 10, no. 11, Nov. 2021, doi: 10.3390/biology10111174.

BIOGRAPHIES OF AUTHORS

Md. Obaidur Rahman is currently is an Associate Professor at European University of Bangladesh. He is also acting as the head of the department role since 2018. He completed his B.Sc. and M.Sc. from Russia. He has published several research articles in reputed journals (Scopus) and international conferences (Scopus). He is currently doing his Ph.D. at Dhaka University of Engineering and Technology. His research interest includes IOT, machine learning, deep learning and optimization problems. He can be contacted at email: obaidur.rahman988@gmail.com.

F. M. Javed Mehedi Shamrat received the B.Sc. degree in Software Engineering from Daffodil International University in 2018. He used to work at Daffodil International University. He has been heavily involved in collaborative research activities with researchers in Bangladesh, USA, Canada, China, Korea and researchers from Australia, especially in machine learning, deep learning and image processing. He has published several research articles in reputed journals (Scopus) and international conferences (Scopus). Mainly his research interests include the IoT, machine learning, data science, android and web applications, image processing, neural network, artificial intelligence, robotics, bioinformatics and deep learning. He can be contacted at email: javedmehedicom@gmail.com.

Mohammod Abul Kashem is currently a professor at Dhaka University of Engineering and Technology. He has published several research articles in reputed journals (Scopus) and international conferences (Scopus). His research area includes Signal processing, algorithm and IOT. Currently he has more than Hundred publications and been a member of many renowned conferences. He can be contacted at email: drkasheml l@duet.ac.bd.

Most. Fahmida Akter earned her bachelor's degree and master's degree in Computer Engineering from the state university "Lvivska Polytechnica" in Lvov, Ukraine, 1996. She went on to work as a software engineer for a software development company after graduation and has been doing so ever since. She is now the company's CTO and has decided to pursue an MPhil at the Bangladesh University of Professionals (BUP). Her research interests include Cyber Physical Systems, the Internet of Things, Artificial Intelligence, and Machine Learning, among other things. She can be contacted at email: faktergm@gmail.com**.**

Sovon Chakraborty is a Lecture at European University of Bangladesh. He completed his B.Sc. from Ahsanullah University of Science and Technology. His ambition is to live freely and generate ideas that will help the people and society around him, after which he wants to disseminate such ideas around the globe. He has published several research articles in reputed journals (Scopus) and international conferences (Scopus). His research area includes Deep learning, aspect-based sentiment analysis, IOT, Industrial fault diagnosis. He can be contacted at email: sovonchakraborty2014@gmail.com.

Marzia Ahmed received her B.Sc. and M.Sc degree in Computer Science and Engineering from Khulna University, Khulna and Dhaka University of Engineering and Technology, Gazipur, Bangladesh in 2013 and 2020 respectively. In 2014 and 2015, she worked as an Analyst Programmer in Southtech Limited, Bangladesh. Since 2016 she worked as a Senior Lecturer and now in the Faculty of Science and Information Technology, Daffodil International University, Dhaka, Bangladesh. Currently doing Ph.D. at Universiti Malaysia Pahang, Malaysia. Her research interests include algorithm optimization, internet of things, machine/deep learning, and artificial intelligence. She can be contacted at email: ahmed.marzia32@gmail.com.

Shobnom Mustary is currently a Ph.D. candidate at Dhaka University of Engineering and Technology. She has published several research articles in reputed journals (Scopus) and international conferences (Scopus). Her research area includes robotics, artificial intelligence and machine learning. She can be contacted at email: shobnom93717@gmail.com