VOL. 18, NO. 15, AUGUST 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

IOT-BASED HEALTH CARE SYSTEM FOR EMOTIONAL AND HEART RATE MONITORING

Zahariah Manap, S. S. Siveneswari and Adam Wong Yoon Khang
Faculty of Electronics and Computer Technology and Engineering, CeTRI, Universiti Teknikal Malaysia Melaka (UTeM), Malaysia
E-Mail: zahariah@utem.edu.my

ABSTRACT

An IoT-based remote health monitoring system helps patient's especially older adults and non-communicable disease (NCD) patients to get medical assistance or advice without being physically present in the hospital or medical centre. This system provides regular health monitoring from anywhere by having access to the Internet. One of the important elements is the physiological parameters which indicate the health status of the monitored patients. Literature study shows that most of the previous works monitor blood pressure, respiratory rate, temperature, ECG, blood oxygenation, diabetes, and hypertension. There have been little works paid attention to measuring the emotional level of the patient. Therefore, this paper explains the development of an IoT-based health monitoring system that measures the emotional level of the patient apart from other essential physiological parameters. The system consists of a microcontroller, two sensors, a wireless communication module, and an IoT cloud display, focusing on measuring the heart rate, body temperature, SpO2, and emotional level. For the heart rate and body temperature readings, the measurements acquired from the developed system show a close agreement with those of the established brand ROSSMAX with an error of less than 5%. For the emotional level test, there are 83.3% out of twelve subjects agree that the GSR value shows her feeling.

Keywords: health monitoring, IoT, smart healthcare.

Manuscript Received 2 July 2020; Revised 23 September 2023; Published 10 October 2023

1. INTRODUCTION

The advent of Internet of Things (IoT) technologies has enabled the development of a remote health monitoring platform that helps patient's especially older adults and non-communicable disease (NCD) patients to get medical assistance or advice without being physically present in the hospital or medical centre. It also gives advantages to medical experts by broadening the market rather than relying on only traditional clinic settings. The IoT-based health monitoring platform allows the physical condition of the patients to be transmitted to the healthcare service providers in real-time and recorded for future reference. In return, the patients may obtain immediate feedback on their vital signs such as heart rate, body temperature, blood pressure, respiration rate, and even their body movement. Therefore, necessary action can be taken immediately according to the patient's condition. The platform is accessible everywhere through mobile devices, emails, or desktops as long as the internet connection is available. Medical experts are also taking advantage of these smart devices which causes the field of IoT to be rapidly developed in the healthcare industries.

A recent study conducted by Junde Li *et al* [1] has shown the importance of providing healthcare to elderly citizens. The study also highlighted the role of technology in enhancing the quality of life for older adults. This view is supported by Manogaran *et al* [2] who focused on the data management and security issues of the healthcare big data system. Aiming to provide meaningful and secure data out of a huge patient database, the authors proposed a well-organized data management architecture for IoT-based continuous health monitoring consisting of several phases which are data collection, data transfer, and data storage phases. Some other approaches are also applied to process, manage, and protect the health monitoring data. One of the advanced methods is called data mining as described in a survey carried out by Jose Reena K and R. Parameswari [3].

Numerous works have been carried out to develop IoT-based devices that support remote health monitoring. One of the important elements in a real-time IoT-based health monitoring system is the physiological parameters that indicate the health status of the monitored patients. The parameters are measured by using biomedical sensors which are attached to the patient's body or wearable devices. Much of the available work commonly monitors blood pressure, respiratory rate, temperature, ECG, and blood oxygenation [4]–[8]. Other interesting physiological parameters are type 2 diabetes and hypertension as focused in [9]. However, there have been little works paid attention to measuring the emotional level of the patient. Therefore, this paper explains the development of an IoT-based health monitoring system that measures the emotional level of the patient apart from other essential physiological parameters.

The rest of the paper is structured as follows. The next section gives the background study on IoT-based health monitoring systems and discusses some earlier works. Then, the methodology of this project is explained in the third section, followed by the results and analysis. The last section concludes our work and plans.

2. IOT-BASED HEALTH MONITORING SYSTEM

Generally, an IoT-based health monitoring system comprises of a data acquisition block, wireless communication module, and cloud interface for data

VOL. 18, NO. 15, AUGUST 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

representation as depicted in Figure-1. The data acquisition component consists of specific sensors that measure intended physiological parameters. The most common sensors used are pulse rate sensor, body temperature sensor [10], ECG sensor [4], airflow sensor for heart response, and SpO2 sensor [6]. From the literature, an IoT-based health monitoring system can handle more than one sensor and the maximum number of sensors depends on the microcontroller's capability [11]. In this paper, we use two sensors which pulse oximeter and heart rate sensor, and a galvanic skin response sensor (GSR) to measure the emotional level. As the sensors are non-invasive, they are attached to the patient's body in a wearable device.

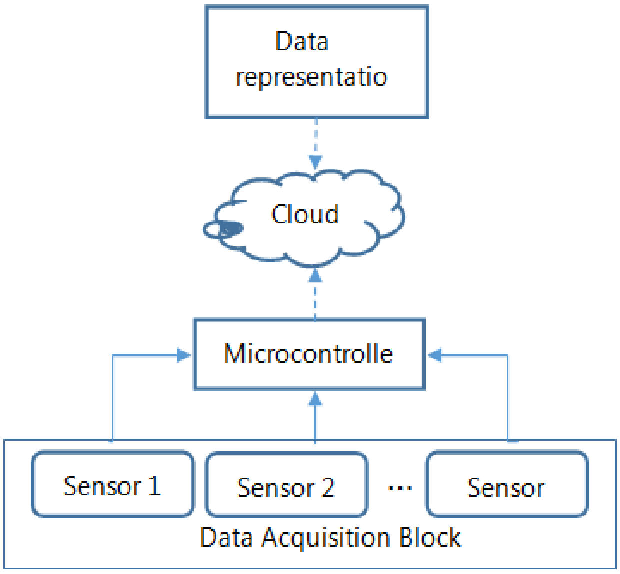

Figure-1. General block diagram/components of an IoT-based health monitoring system.

The physiological data acquired by the sensors are fed into the microcontroller to be processed. Processing is executed by the microcontroller. Most of the works thus far used either Arduino [4], [6], [7] or Raspberry Pi [5], [8] to do the data processing and as the system hub. The microcontroller is also responsible for feeding the processed data to the cloud interface through a wireless communication module. Much of the available works have used Wi-Fi [4]–[6], [8], [9] to provide internet access to the system. Other than Wi-Fi, some authors embedded a GSM module [5] to provide SMS capability. Despite most of the previous works focused on long-range IoT-based health monitoring systems, the authors in [7] proposed an in-building (inside hospital) system that used an Xbee module to provide communication between patient devices and health care personnel.

Cloud storage is a very important component that enables the data to be stored and accessed by the user. Thingspeak, Blynk, and Adafruit are widely used IoT cloud platforms to perform the data representation task in most of the current works.

3. METHODOLOGY

This work aims to develop an IoT-based health monitoring system that measures and displays a patient's heart rate, body temperature, oxygen level (SpO2), and emotional level. Figure-2 and Figure 3 show the block diagram and the laboratory prototype of the developed system respectively. The components in the dashline box form the patient's device which is positioned at the monitored patient's side. The data representation is represented by the Blynk application as the IoT cloud platform. The Blynk Apps will store and display the data received from the user's device through a wireless communication medium.

The sensors used in this system are a type of non-invasive sensors. The sensors are attached to the skin of the patient to detect his/her physiological parameters. The first sensor used is a Pulse Oximeter and Heart Rate sensor (MAX30100) which measures the heart rate, body temperature, and SpO2. It consists of 7 pins powered up by 1.8V and 3.3V. The infrared light functions to measure the pulse rate. The red light and infrared light is used to detect the oxygen level in the blood. Another sensor used in this system is a GSR sensor (CJMCU-6701) which measures the emotional level. The sensor assesses the function of the sweat gland that is related to the emotional level of the user. It measures the conductivity of the skin. The greater the sweat gland activity, the greater the perspiration causing lower resistance of the skin. This causes higher skin conductivity as stated by Ohm's Law. Using this principle, we can relate the value of measured current to the patient's emotional level.

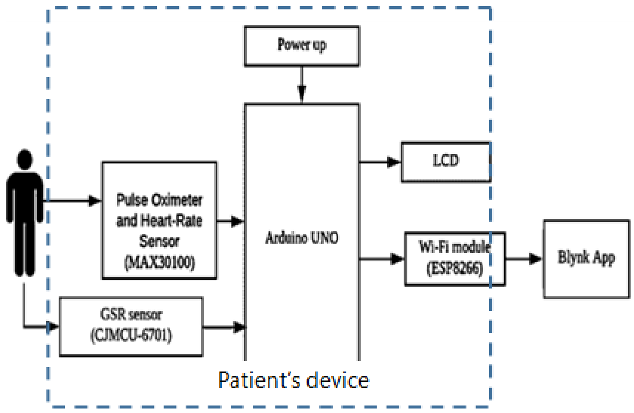

Figure-2. Block diagram of the developed system.

A low-cost Arduino UNO is used as the microcontroller for the system. It functions with ATmega328P AVR and uses Arduino IDE software to program. The board consists of 14 digital pins of input/output and is powered up by a 5V DC source. The Serial pin 0 (*Rx*) and pin 1 (*Tx*) are used to receive and transmit the Transistor-transistor logic (TTL) serial data. The board allows the operation to be reset by pressing the reset pin 'LOW'. The Arduino UNO is the heart of the project that receives the data from the MAX30100 and GSR sensors. The microcontroller will process the input

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

data and translate it to the heart rate, body temperature, oxygen level, and emotional level of the user or patient before sending the output to the cloud platform. The output data are also displayed on an LCD embedded in the patient's device.

The software used to program the Arduino is Arduino IDE which uses C language programming. The programming done will configure the Arduino to send an alert message when the heart rate of the user or patient is above 100 bpm or less than 60 bpm. As for body temperature, it is configured for an alert message when the body temperature is more than 37 degrees Celsius. The ESP8266 Wi-Fi module is configured using the hotspot, authentication token, password, and Blynk App virtual pin. The GSR sensor does not have an alert message.

An ESP8266 Wi-Fi module is used to provide wireless communication between the patient's device, IoT cloud platform, and data representation on the user display. The function is to connect to a hotspot and connect to the internet. It only functions with a power supply of 3.3V. The authentication token is used to connect to the wifi module. The health care personnel can retrieve the data from the Blynk App on a smartphone. The data can be exported as a CSV file for future reference and for the health care centre to take appropriate action if there is any abnormality traced in the gathered data.

Figure-3. The laboratory prototype of the developed system.

4. RESULTS AND DISCUSSIONS

In this project, the Arduino UNO is used to read and process the data acquired from the sensors and send the output to the IoT platform. The microcontroller is programmed to detect abnormalities in the readings and notify the user if the situation happens. For a healthy person, the range of heart rate, SpO2, and body temperature should be 60-100bpm, 96%-100%, and 36-38 degrees Celsius respectively. The GSR value for a stable or calm person is between 2 and 100 micro Siemens (µS). The MAX30100 requires a few minutes to be stable when the device is turned on. The reading of the MAX30100 sensor is unstable for approximately 2 minutes. Figure-4 shows the LCD indicating the system is just turned on.

Figure-4. LCD when the device is turned on.

After the system is initialized, the sensors are ready to be attached to the user's body. In this testing stage, we attach the sensors at the wrist where the pulse rate can be easily detected as shown in Figure-5. The tests are done on 8 participants.

Figure-5. Attaching the sensors to the skin.

To examine the accuracy of the developed system, we take the average of six readings for each case. Then, compare the average with the reading taken by other possible methods for each of the physiological parameters. For heart rate, we acquired the reading by using a well-established heart rate monitoring device, ROSSMAX AV151 monitoring device. We also take the reading by using the heart rate sensor embedded in the Samsung S6 smartphone as well as manual reading by using our fingertips. For body temperature, we compare it with the data taken by a ROSSMAX digital thermometer. However, as for the output of the GSR sensor, we couldn't find any appropriate equipment for comparison. Therefore, we validate the data by asking questions to the user on their emotional level by distributing the Google form to prove the reading.

Figure-6 shows an example of reading obtained by the developed system. All four physiological parameters are displayed in one graph and the current reading which is taken in real-time is displayed on top of the graph. The Blynk Apps can display the data for up to several months. Users can export the data into a CSV file.

Figure-6. Parameters and graphs are displayed in the Blynk App

VOL. 18, NO. 15, AUGUST 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

In the case of the reading shows abnormalities, a notification alert will be sent to a pre-set email address which can be the health care personnel's email address. Figure-7 shows an example of the alert sent to the email.

Figure-7. Notification when alert message is sent to email.

The data acquired by the developed system can also be monitored through the Arduino IDE platform as shown in Figure-8. The readings obtained from the sensors are displayed continuously in terms of numerical values and graphs.

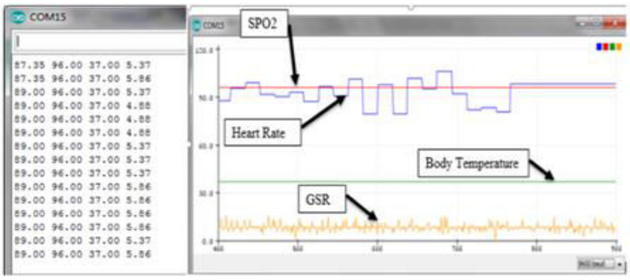

Figure-8. Output displayed in Arduino IDE.

Table-1 summarizes the average heart rate reading taken by our system in comparison to the other three methods for eight persons. As shown in Table-1, the readings for all four methods are between 60 to 100 bpm which proves that the readings taken are valid as a normal heart rate should be within the range stated.

Table-1. Comparison between IoT-based HMS and other methods for heart rate readings.

IoT-based Health Monitoring System	ROSSMAX BP and HR Monitor	Samsung S6	Manual Reading
89.98	85	67	72
74.42	70	71	72
66.96	92	89	84
86.59	72	82	78
72.08	73	73	72
73.20	73	92	87
76.54	77	78	78
68.54	69	66	72

The accuracy of our developed system with compared to other methods is shown in terms of percentage error as in Figure-9. From the graph of Figure-9, we can see that our system gives a close reading when compared to the ROSSMAX brand. The percentage error is less than 5% except for person 3 and person 4. The large percentage error of about 20% for person 3 and person 4 is caused by the sensitivity of the heart rate sensor used in our system. When compared to the heart rate sensor on the Samsung S6 and manual reading, it shows an unstable pattern of accuracy.

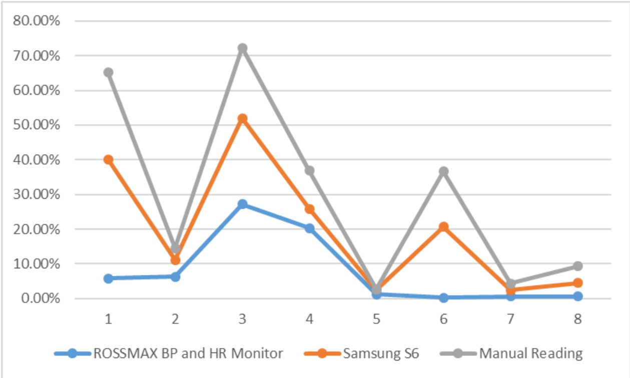

Figure-9. Graph of heart rate comparison for four types of devices.

Table-2 summarizes the percentage error of body temperature reading taken by our system with comparison to the ROSSMAX digital thermometer.

Table-2. Comparison between IoT-based HMS and ROSSMAX digital thermometer for body temperature readings.

IoT-based Health Monitoring System	ROSSMAX Digital Thermometer	Percentage error (%)
36.63	36.5	0.36%
37.10	36.5	1.64%
37.10	36.6	1.37%
37.00	36.9	0.27%
37.00	36.2	2.21%
37.10	36.8	0.82%
35.00	34.5	1.45%
37.00	36.9	0.27%

From Table-2, we can see that our system gives a close reading when compared to the ROSSMAX brand. The percentage error is less than 2.5%. To see the persistence of our system, we take 30 consecutive readings for one person as shown in Figure-10.

ARPN Journal of Engineering and Applied Sciences

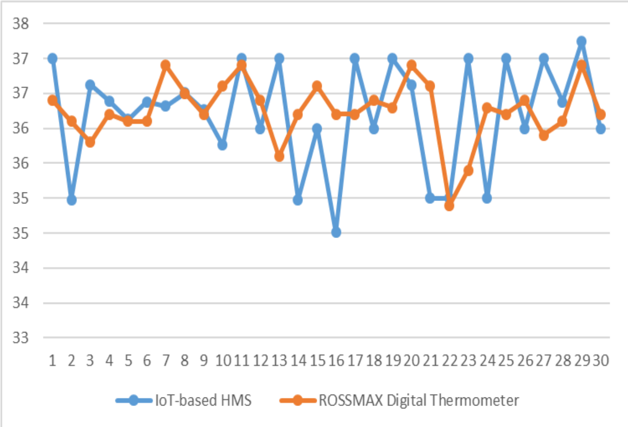

Figure-10. Graph of 30 data taken on the same user for body temperature.

As can be seen in the graphs of Figure-10, the percentage error calculated from the data taken is less than 5% which proves that the device development is applicable. The maximum percentage error is 4.67%. The data is taken 30 times to see the persistency of the developed system in acquiring body temperature readings.

The reliability of GSR measurement is tested on twelve subjects who are the students. As we can see in Figure 8, the GSR values are constantly low, showing that the subject is in a stable or normal state. This observation closely agrees with the findings on GSR values explained in [12]. According to the authors, when a user has good sleep quality, the GSR values stay at a relatively constant level.

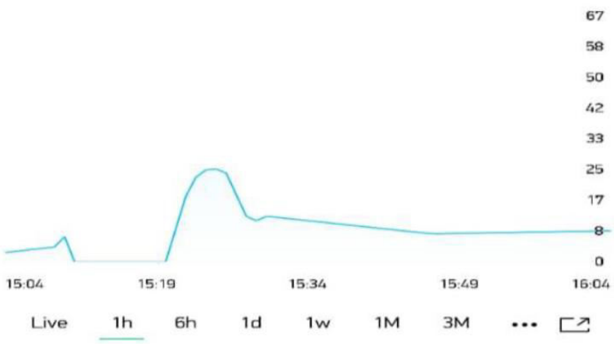

Figure-11. The GSR reading fluctuates when the person is not at a normal emotional level.

In this project, we relate the GSR value with the subject's emotion. When the subject has a disturbance in her emotion, the GSR value will spike as depicted in Figure-11. To validate the observation, the subjects are asked about their emotion at the time the reading is taken. Out of twelve subjects, 83.3% agree that the GSR value shows their feeling, while 16.7% were not sure as described in the chart of Figure-12.

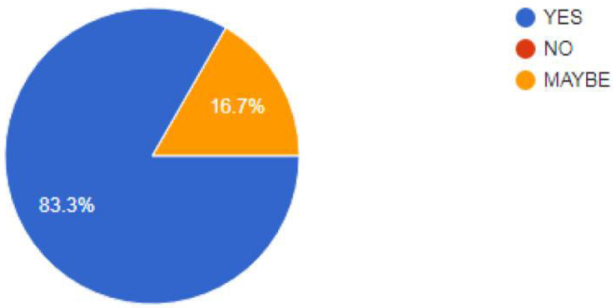

Figure-12. Pie chart for the questions on the GSR sensor.

5. CONCLUSIONS

In this paper, we explain the development of an IoT-based health monitoring system that consists of a microcontroller, two sensors, a wireless communication module, and an IoT cloud display. The contribution of this work is that we add a rarely focused physiological parameter in the system which is the emotional level apart from three ordinary parameters of interest: heart rate, body temperature, and SpO2. This system provides real-time access to every 10 seconds of data update acquired from two sensors located at the user's side through internet access. From several tests we have run on the heart rate and body temperature readings, the measurements acquired from the developed system show a close agreement with those of the established brand ROSSMAX. For the emotional level test, there are 83.3% out of twelve subjects agreed that the GSR value shows their feeling, while 16.7% were not sure.

To conclude, even though the developed system shows promising results, we believe that it should provide more accurate measurements due to the criticalness of the medical applications. In our future work, more accurate sensors will be used. A meticulous study should be carried out on the signals acquired from the GSR sensor. Possible ways to be implemented are by imposing a signal processing technique and machine learning approach.

ACKNOWLEDGEMENT

The authors would like to thank Universiti Teknikal Malaysia Melaka (UTeM) and the Ministry of Higher Education (MOHE), Malaysia for sponsoring this work under project PJP/2019/FTKEE (4B)/S01656.

REFERENCES

[1] J. Li, Q. Ma, A. H. Chan, and S. S. Man. 2019. Health monitoring through wearable technologies for older adults: Smart wearables acceptance model. Appl. Ergon. 75(September 2018): 162-169.

[2] G. Manogaran, R. Varatharajan, D. Lopez, P. M. Kumar, R. Sundarasekar and C. Thota. 2018. A new architecture of the Internet of Things and big data ecosystem for secured smart healthcare monitoring

VOL. 18, NO. 15, AUGUST 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

and alerting system. Futur. Gener. Comput. Syst. 82: 375-387.

[3] K. Jose Reena and R. Parameswari. 2019. A Smart Health Care Monitor System in IoT Based Human Activities of Daily Living: A Review. Proc. Int. Conf. Mach. Learn. Big Data, Cloud Parallel Comput. Trends, Prespectives Prospect. Com. 2019. pp. 446-448.

[4] F. Shanin et al. 2018. Portable and Centralised E-Health Record System for Patient Monitoring Using Internet of Things(IoT). 2018 Int. CET Conf. Control. Commun. Comput. IC4 2018. pp. 165-170.

[5] K. N. Swaroop, K. Chandu, R. Gorrepotu and S. Deb. 2019. A health monitoring system for vital signs using IoT. Internet of Things. 5: 116-129.

[6] K. A. Zilani, R. Yeasmin, K. A. Zubair, M. R. Sammir and S. Sabrin. 2018. R3HMS, An IoT Based Approach for Patient Health Monitoring. Int. Conf. Comput. Commun. Chem. Mater. Electron. Eng. IC4ME2 2018. pp. 1-4.

[7] A. B. Fakhri, S. K. Gharghan and S. L. Mohammed. 2018. Statistical validation of patient vital signs based on energy-efficient wireless sensor network monitoring system. ARPN J. Eng. Appl. Sci. 13(20): 8258-8270.

[8] S. Senthilkumar, K. Brindha, R. Charanya and A. Kumar. 2019. Patients health monitoring system using IOT. Indian J. Public Heal. Res. Dev. 10(4): 252-256.

[9] A. Goyal et al. 2020. Smart Home Health Monitoring System for Predicting Type 2 Diabetes and Hypertension. J. King Saud Univ. - Comput. Inf. Sci.

[10] A. Nishitha Reddy, A. Mary Marks, S. R. S. Prabaharan and S. Muthulakshmi. 2017. IoT augmented health monitoring system. 2017 Int. Conf. Nextgen Electron. Technol. Silicon to Software, ICNETS2 2017. pp. 251-254.

[11] V. Pardeshi, S. Sagar, S. Murmurwar and P. Hage. 2017. Health monitoring systems using IoT and Raspberry Pi - A review. IEEE Int. Conf. Innov. Mech. Ind. Appl. ICIMIA 2017 - Proc., no. Icimia. pp. 134–137.

[12] Y. Du, Q. Sun, K. Wang and T. Y. Tang. 2019. A Lightweight and Affordable Sleep Quality Monitoring and Visualization System with a GSR Sensor for Users in Rural Areas to Facilitate Tele-Health. pp. 41-49.