Smart Healthcare Monitoring System Using IoT

https://doi.org/10.3991/ijim.v17i01.34675

Bzhar Ghafour Mohammed(✉), Dler Salih Hasan
Salahaddin University, Erbil, Iraq
bzhar.mohammed@su.edu.krd

Abstract—The progress in communication and information technology has contributed to the creation of the Internet of Thing (IoT). Internet of Things today plays a crucial role in tracking, documenting, storing, presentation and communication in variety of fields like healthcare, smart cities, engineering, and others. Using an IoT-based monitoring system, the critical parameters of health are tracked and data transmitted via network. Data will be accessed for the benefit of the patient's current condition. This research paper focused on remote monitoring of body temperature (DS18B20), heart rate and SPO2(MAX30100), additionally the position of patient can be obtained on demand using SIM7600E GSM and GNSS HAT (Hardware attached on top) Module. Raspberry Pi 4B used as microcontroller to gather data from health parameter sensors. The data from sensors transmitted into cloud storage through a network. The proposed system uses last version of IoT microcontroller and devices were used which significantly affected the precision and speed of the whole system. A GUI cross platform mobile application was developed for presenting real-time data to both doctors and patients. The system is beneficial for synchronous monitoring of patient's health status hence allowing urgent medical decision by doctors at right time.

Keywords—Internet of Things, healthcare, remote monitoring, SPO2, raspberry pi, GUI, real-time, DS18B20, MAX30100

1 Introduction

The internet has grown particularly as a result of its accessibility to everyone. The Internet of Things results in an electronic access control system that enables a user to do a variety of tasks more quickly, productively, and safely. IoT is a technological advancement that has the potential to improve people's lives by utilizing smart devices and smart sensors that communicate via the internet [1]. With the rapid progression of technology, each country now places a high priority on Internet of Things application. The concept of internet-of-things (IoT) is one of the next revolutionary developments in internet-based computing, and it is now having a positive effect in a wide range of application fields such as smart cities, healthcare, engineering, and others. [2]. Internet of Things (IoT) is the latest internet advancement, including the field of health care study. This remote healthcare monitoring has grown too fast with the use of wearable sensors and smartphones. IoT health screening aids in disease spread prevention as well as accurate evaluation of health status, regardless location of the doctor furthermore it is facilitating continuous health condition monitoring. The Remote Healthcare Monitoring arrangement enables patients to be observed outside of traditional hospital environments (for example, at home), and increases access to human resources offices while lowering costs [3].

Health care providers can monitor patients' health status using a number of crucial health parameters. Due to major health problems, certain people with chronic diseases require continuous monitoring. These parameters include heart rate, blood pressure, body temperature, spo2, respiratory rate, ECG, and blood sugar. Most of these health parameters can now be tracked using electronic devices with precise sensors thanks to advancements in medical technology. These parameters can be tracked remotely due to developments in communication technology, particularly the internet, making IoT healthcare monitoring possible.

There are several available microcontrollers for Internet of things choosing one of them depends on project requirement and specification, raspberry pi is one of the advanced popular microcontrollers used recently. The Raspberry Pi is a miniature pc that is used for simple computing and networking tasks. It is the primary component of the internet of things. It allows connectivity to the internet, allowing the automation system to be linked to a remote controlling device [4]. Regardless of the kind of microcontroller, there are numerous sensors for receiving signals from the outside world, such as health care monitoring sensors including body temperature sensors, heart rate sensors, pulse oximeter sensors, ECG sensors, blood pressure sensors, and so on. In addition to the sensors other hardware can be added for the microcontroller like GSM, GPS, GNSS and so on. The data from various sensors and hardware after processing by microcontroller should be transmitted to and stored in a cloud storage via a network.

This research paper proposed an IoT system for monitoring health status of patients who are in need for continuous prolonged follow up and monitoring by their doctors. Raspberry Pi 4B microcontroller and python as programming language had been chosen for gathering data from sensors then processing and transmitting into cloud storage through a network. To store data, the MySQL database is employed as cloud storage. The three vital health parameters which are body temperature, heart rate and SPO2 are monitored in real-time through two sensors; body temperature sensor and oximeter sensor. Furthermore, the patient's location determined by a GSM/GPRS/GNSS HAT module if necessary. The aforementioned HAT is also used to send SMS notification via a SIM card in case of abnormal health parameters.

The system also comprised a cross-platform mobile application (i.e., Android and IOS compatible) for GUI to display real-time health parameters' value, alerts and notifications for both patients and paramedics/doctors. The system hardware was configured in a wearable model. The proposed system provides both real-time data and history of health parameters for patients and doctors with sending notifications and alerts in necessary and emergency situations remotely. This allows making life saving decisions by doctors without need for physical presence in clinics and hospitals.

2 Literature survey

The IoT-based Healthcare Monitoring System for War Soldiers by Gondaliaa, et al. in 2018, suggested a system that would enable the soldiers who are missing and wounded in the warfare to track the location in actual time and control their health. It helps to reduce time of the exertion of the army control unit to find and rescue [5].

The research paper of Durán-Vega et al. in 2019, proposed an IoT System for Remote Health Monitoring in Elderly Adults through a Wearable Device and Mobile Application. They employed a biometric bracelet connected to a mobile application, which offers real-time viewing of all the data collected by the sensors in the bracelet (pulse rate, blood oxygen saturation and Body temperature). Caretakers can use this information to make decisions regarding their patients' wellbeing. Their study describes the design and implementation of an IoT system for remote monitoring of elderly persons in nursing homes using a smartphone application and a wearable device. The creation of the prototype demonstrated that it is viable to carry out and implement the research project. Furthermore, it is low-cost and compatible with the IoT paradigm; the most essential features are: real-time monitoring of the general status of the patients [6].

A smart healthcare monitoring system designed by Naik & Sudarshan in 2019.Their IoT platform system based on the Raspberry Pi. The system used Wi-Fi network technologies to identify human body parameters like body temperature, blood pressure, heartbeat, accelerometer, ECG, respiration, and other data on server of the internet of things [7].

In their research paper Valsalan, et al. in 2020, suggested an IoT-based health tracking device with a mobile physiological screening mechanism that can continuously screen the patient's temperature, heartbeat and other specific necessary parameters. They suggested a continuous monitoring and control instrument to screen the patient status and archive the patient data in a server using a wi-fi based module remote communication [3].

The research paper of D.Acharya & N.Patil in 2020, described IoT-based Health Care Monitoring Kit, the concept and deployment of an IoT-based smart doctor package for a vital medical situation that can provide robust access to IoT data to assist emergency health providers like Intensive Care Units. This system has developed to give the doctors the required history of patient health in real-time [8].

In 2020, Godi et al. published an article in which they presented the E-Healthcare Monitoring System (EHMS), an IoT technology platform that they combined with machine learning (ML) techniques to create an advanced automated system. The patient's data is collected by an IoT wearable sensor. The data obtained from a variety of health monitoring devices is fed into an E-Health care management system. After that, EHMS analyzes the health status by using machine learning techniques on raw data [9].

Sangeethalakshmi, et al. in 2021, published an article in which they presented a patient health monitoring system using IoT, the suggested system included of mobile application and GSM for continuous monitoring of patients remotely. Sensors include a data acquisition unit, a microcontroller (ESP32), and a software system. The system continuously monitors, shows, and saves patients' temperature, heart rate, ECG, blood pressure, and SPO2, and the same information was sent to doctors [10].

3 System hardware component

3.1 Microcontroller

Raspberry pi 4B. The Raspberry Pi 4B is a single-board computer that features a 64-bit quad-core ARM8 Broadcom BCM2711 1.5 GHz CPU, 4GB LPDDR4 RAM, an expandable MicroSD card and a standard 40-pin GPIO header. Raspberry Pi 4 comes with Gigabit Ethernet, along with onboard wireless networking and Bluetooth [11]. When combined with Wi-Fi and Internet connectivity, it is easy to set it up for remote communication, which makes the Raspberry Pi perfect choice for IoT applications. These were the reasons behind selecting raspberry pi microcontroller in this proposed system.

3.2 Sensors

Body temperature. The DS18B20 temperature sensor used to measure body temperature. The advanced features of the employed temperature sensor include a 1-wire interface and a 64-bit serial stored in an on-board ROM. It runs on a 3.0v-5.5v power supply [12]. This sensor is quite precise, measuring the temperature within about 0.05°C of the actual temperature. It can withstand temperatures as high as 125°C. Because this device contains an integrated analog to digital converter, unlike the other sensors for example TMP36, which is an analog device, DS18B20 is relatively easier to integrate with the Raspberry Pi.

Pulse oximeter. The MAX30100 sensor selected in this proposed system for measuring blood oxygen level (SPO2) and pulse rate. The sensor has a pulse oximetry and heart rate monitor sensor. It includes two LEDs, one of which generates infrared light and the other red light. Only single infrared LED is required to determine the heart rate, and both LEDs are required to measure the oxygen content in the blood. When the heart beats, the oxygenated blood rises, and when the heart is at rest, the oxygenated blood drops. The period between the rise and drop of oxygenated blood can be used to determine the heart rate. Deoxygenated blood absorbs more infrared spectrum of light while passing more red spectrum of light, and oxygenated blood absorbs more red spectrum of light while passing more infrared spectrum of light. The absorption rates for both light sources detected by the sensor are saved in a buffer that may be retrieved using the I2C protocol through the Grove port. The GitHub raspberry pi MAX30100 library is used to calculate the pulse rate and SpO2 levels from sensor input. The MAX30100's accuracy was compared to the commercial HR and SpO2 monitoring instrument General care®. the sensor output data's error rate and accuracy, resulting in a relatively low error value of 2.89% and an accuracy of 97.11% for the heart rate data. The data calibration of SpO2 also provides favorable results, with an error value of 1.15% and a high accuracy rate of 98.84% [13] [14].

3.3 Hardware extension

4G GSM, GPRS and GNSS HAT module. For efficient communication and tracking location, this HAT was attached to the raspberry pi microcontroller with the following features:

- Enables LTE Cat-4 4G / 3G / 2G Communication & GNSS Positioning
- Compatible With Raspberry Pi
- Dial-Up on Windows/Linux
- Communication protocols supported are TCP/UDP/FTP/FTPS/HTTP/HTTPS
- Telephone Call & SMS Support

Figure 1 shows all hardware components of the proposed system.

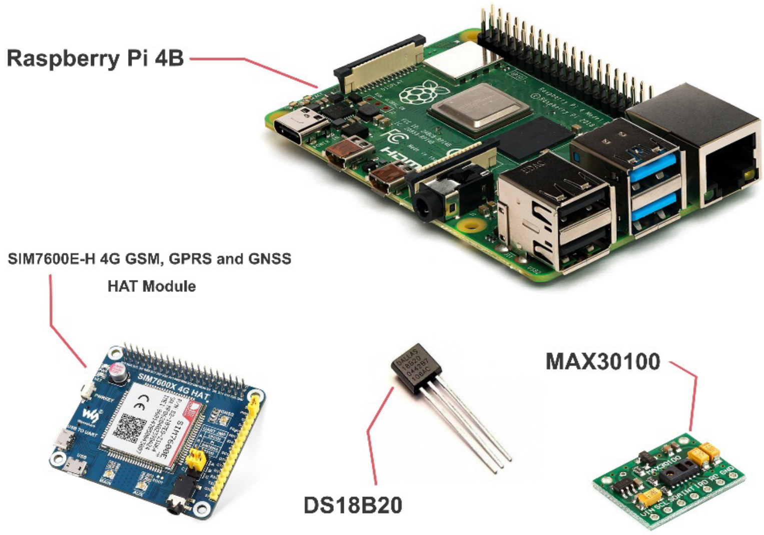

Fig. 1. Raspberry Pi 4B with SIM7600E-H 4G GSM, GPRS and GNSS HAT module, DS18B20 body temperature sensor and MAX30100 pulse oximeter

The Figure 2 shows the schematic of hardware healthcare monitoring system components used in this research paper.

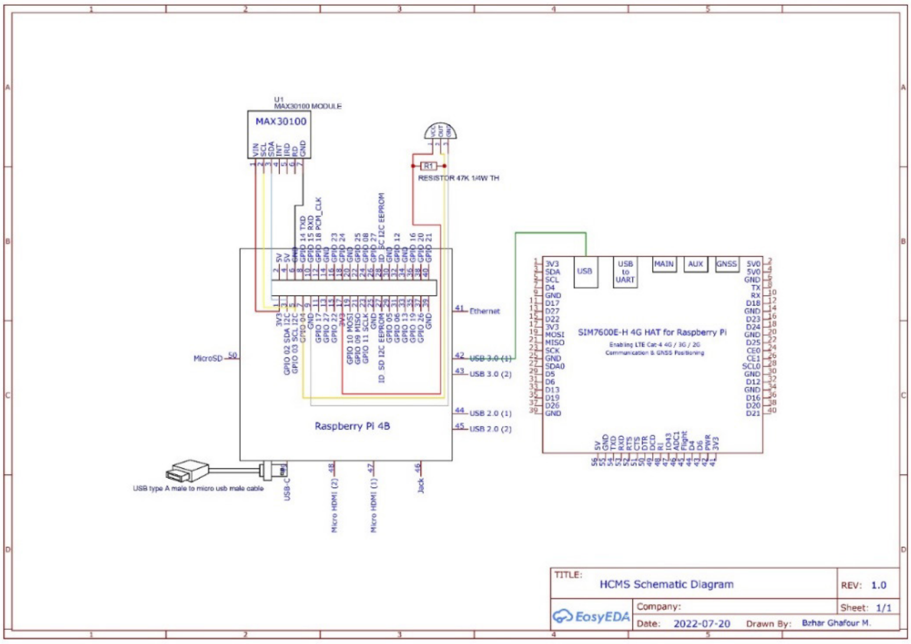

Fig. 2. System hardware component schematics

4 Software and programming language

4.1 Python programming language

Python programming language used for programming raspberry pi microcontroller to read sensors data and transmitting it to cloud storage and the library of sensors were written by python. Python could be used to construct cross-platform applications as well as Web, mobile, and scientific applications.: In general, the same Python program may be launched on Windows and Unix-like systems like Linux, BSD, and Mac OSX s [15].

4.2 Flutter and Dart

Flutter is an open-source platform that leverages Dart as its programming language to create natively built and cross-platform applications from a single codebase. Flutter and Dart were both developed by Google. In this proposed system Flutter and Dart were used to create a cross-platform mobile application (i.e., Android and iOS compatible) for displaying real-time health parameter values, alerts, and notifications for both patients and paramedics/doctors.

4.3 MySQL

MySQL is the world's most popular open-source database. Whether you are a rapidly developing online property, a technology ISV, or a huge company, MySQL can help you build high-performance, scalable database systems at a low cost. In this suggested system, MySQL was used as cloud storage to store data from various sensors and hardware after it has been processed by the microcontroller. The required information of the patient, doctors/paramedics and record of abnormal data also stored in database. The recorded data can be used to find the past information of the previous patient status.

5 Proposed system and working method

Important healthcare parameters remotely tracked in real-time and measured value presented to doctors and patients through a system-specific mobile application. The healthcare parameters are SPO2, heart rate and body temperature. The hardware configured by connecting sensors to the raspberry pi microcontroller. The 4G GSM, GPRS and GNSS HAT Module attached to the raspberry pi which was connected to the MySQL database via Wi-Fi. the raspberry pi and sensors programmed by python language for gathering, analyzing and transferring data. Each sensor was placed to specific defined location of patient’s body, as the temperature sensor placed to the skin and the pulse oximeter to the fingertip. after measuring health parameters, it will compare with its normal reference range then all values are presented to the mobile application, if there is any abnormal value i.e., any value below or above normal range, an emergency alert will send to doctors/paramedics and relative of the patients via SMS notification with patient’s position thus allowing doctors to make life-saving decisions without requiring patients to be present in clinics and hospitals. Figure 3 shows the flowchart of proposed system.

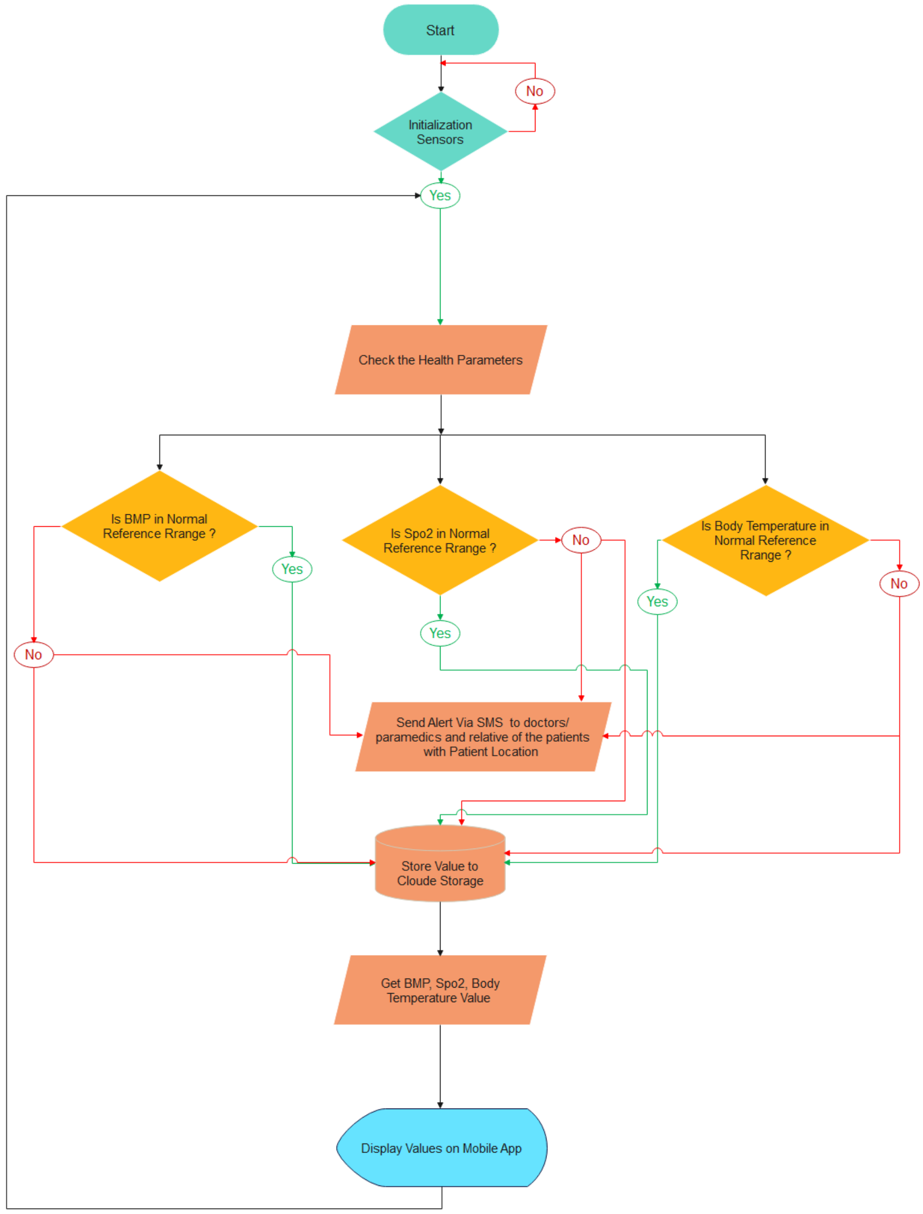

Fig. 3. IoT based smart healthcare monitoring system flow chart

The reference ranges for the involved health parameters shown in Table 1.

Table 1. Reference range of SPO2, heart rate and body temperature [16] [17] [18]

Health Parameters	Normal Reference range	Note
Spo2	95 % -100 %	90% - 94% Borderline
Heart Rate	(60 – 100) bpm	10 years and older - adults
	(70 – 190) bpm	Neonate
	(80 – 160) bpm	Infant (1 – 11) months
	(70 – 130) bpm	Children (1 – 9) years
	(40 – 60) bpm	Athletes
Body Temperature	36.4 C – 37.6 C	11 years and adults below 65 years

6 Testing and results

The hardware devices properly configured and all sensors connected to the raspberry pi microcontroller and a portable power bank used for power supply, The reference range for each health parameter was defined based on available medical resources, then after calibration of sensors data were done precisely. the data was successfully received from sensors by microcontroller, then transferred to the MySQL database server after processing and analysis.

The proposed system was then tested on 30 persons (Rest State) in two groups; healthy individuals and patients in different age and both genders. The patients were chosen from an emergency hospital. The value of Spo2, heart rate and body temperature were shown in the system specific mobile application interface in real time as shown in Figure 4. In the case of an abnormal state for each parameter, when the value was below or above the normal reference range, the system will send an SMS alert to doctors/paramedics and the patient's relative, providing information about the abnormal health parameters and the patient's position for making appropriate decisions and taking necessary measures for proper management and saving patient's life. The information about location of the patient facilitates the process of sending ambulance. Beside receiving alert notifications when a health parameter value was abnormal, clinicians can remotely monitor all recorded health parameters in real-time. Table 2 displays the data obtained from seven individuals and the Figure 4 shows the picture of an individual during collecting health parameters data by the system.

Table 2. Recorded data for SPO2, heart rate, and body temperature

#	Spo2	Heart Rate	Body Temperature
P1	99 %	81 Bmp	35.9 °C
P2	96 %	107 Bmp	36.5 °C
P3	95 %	98 Bmp	37.0 °C
P4	96 %	82 Bmp	37.2 °C
P5	98 %	79 Bmp	35.92 °C
P6	95 %	86 Bmp	36.24 °C
P7	94 %	67 Bmp	36.61 °C

Fig. 4. Testing of the proposed system

7 Conclusion

Developments in information and communication have brought about the advent of the Internet of Things (IoT). Internet of Things enables more physical sensors/devices to collect data via the internet and provides further methods of data connectivity. Nowadays IoT has affected every part of our life, including health care, smart city, transport, and many more. The health monitoring system was described in this research to offer sufficient patients' health status in real-time to the clinicians remotely. Monitoring the precise state of the patient in the absence of the doctor was developed for effective health purposes. The system collects patient information including Spo2, heart rate and body temperature, in addition to providing patient location information in emergency situation with SMS alert notification in case of presence abnormal health parameters value. The system also includes a cross platform mobile application as graphic user interface for both clinicians and patients. The physical presence of patients and clinicians may be avoided by implementing the suggested system in healthcare management, and the condition of patients with chronic diseases can be monitored remotely for effective intervention, allowing doctors to make life-saving decisions at the right time.

8 Future work

Adding more health parameters to the system based on patients need and doctors request like ECG, Blood Pressure, Respiratory Rate, Urine Output, Fetal Heart Rate and So on.

Development of the system to include a decision making for aiding doctors and paramedics in the management of patients.

9 Conflicts of interest

The authors certify that they do not have conflicting interests to mention with relation to the current research.

10 References

[1] I. S. Areni, A. Waridi, I. Amirullah, C. Yohannes, A. Lawi, and A. Bustamin, "IoT-Based of Automatic Electrical Appliance for Smart Home", Int. J. Interact. Mob. Technol., vol. 14, no. 18, pp. pp. 204–212, Nov. 2020. https://doi.org/10.3991/ijim.v14i18.15649

[2] Rout, S., Patra, S.S., Mohanty, J.R., Barik, R.K., Lenka, R.K. (2021). Energy Aware Task Consolidation in Fog Computing Environment. In: Satapathy, S., Zhang, YD., Bhateja, V., Majhi, R. (eds) Intelligent Data Engineering and Analytics. Advances in Intelligent Systems and Computing, vol 1177. Springer, Singapore. https://doi.org/10.1007/978-981-15-5679-1_19

[3] P. Valsalan, T. A. B. Baomar and A. H. O. Baabood, "IOT BASED HEALTH MONITORING SYSTEM," JCR, Volume 7 , Issue-4: 739-743, 2020, https://doi.org/10.31838/jcr.07.04.137

[4] T. Vineela, J. NagaHarini, C. Kiranmai, G. Harshitha and B. AdiLakshmi, "IoT Based Agriculture Monitoring and Smart Irrigation System Using," *International Research Journal of Engineering and Technology (IRJET) ,* vol. 5, no. 1, 2018.

[5] A. Gondalia, D. Dixit, S. Parashar, V. Raghava, A. Sengupta and V. Sarobin, "IoT-based Healthcare Monitoring System for War Soldiers using Machine Learning", Procedia Computer Science, vol. 133, pp. 1005-1013, 2018, https://doi.org/10.1016/j.procs.2018.07.075

[6] L. A. Durán-Vega, P. C. Santana-Mancilla, R. Buenrostro-Mariscal, J Contreras-Castillo, L. E. Anido-Rifón, M. A. García-Ruiz, O. A. Montesinos-López, and F. Estrada-González. 2019. "An IoT System for Remote Health Monitoring in Elderly Adults through a Wearable Device and Mobile Application" Geriatrics 4, no. 2: 34. https://doi.org/10.3390/geriatrics4020034

[7] K. S. Naik and E. Sudarshan, "SMART HEALTHCARE MONITORING SYSTEM USING RASPBERRY Pi ON IoT PLATFORM," *ARPN Journal of Engineering and Applied Sciences,* vol. 14, no. 4, 2019.

[8] A. D. Acharya and S. N. Patil, "IoT based Health Care Monitoring Kit," 2020 Fourth International Conference on Computing Methodologies and Communication (ICCMC), 2020, pp. 363-368, https://doi.org/10.1109/ICCMC48092.2020.ICCMC-00068

[9] B. Godi, S. Viswanadham, A. S. Muttipati, O. P. Samantray and S. R. Gadiraju, "E-Healthcare Monitoring System using IoT with Machine Learning Approaches," 2020 International Conference on Computer Science, Engineering and Applications (ICCSEA), 2020, pp. 1-5, https://doi.org/10.1109/ICCSEA49143.2020.9132937

[10] K. Sangeethalakshmi, S. P. Angel, U. Preethi, S. Pavithra and V. S. Priya, "Patient health monitoring system using IoT," *Materials Today: Proceedings,* pp. 2214-7853, 2021, https://doi.org/10.1016/j.matpr.2021.06.188

[11] "Raspberry Pi Foundation," January 2021. [Online]. Available: https://datasheets.raspberrypi.com/rpi4/raspberry-pi-4-product-brief.pdf

[12] Ramesh Saha, S. Biswas, S. Sarmah, S. Karmakar and P. Das, "A Working Prototype Using DS18B20 Temperature Sensor and Arduino for Health Monitoring", SN Computer Science, vol. 2, no. 1, 2021, https://doi.org/10.1007/s42979-020-00434-2

[13] S. Rao, "IoT Enabled Wearable Device for COVID Safety and Emergencies", Int. J. Interact. Mob. Technol., vol. 15, no. 03, pp. pp. 146–154, Feb. 2021, https://doi.org/10.3991/ijim.v15i03.17815
[14] N. N. Sari, M. N. Gani, R. A. Maharani and R. Firmando, "Telemedicine for silent hypoxia: Improving the reliability and," *Indonesian Journal of Electrical Engineering and Computer Science,* vol. 22, no. 3, p. 1419~1426, 2021, http://doi.org/10.11591/ijeecs.v22.i3.pp1419-1426
[15] C. Dow, Internet of Things Programming Projects: Build modern loT solutions with the Raspberry Pi 3 and Python, Bermingham: Packt Publishing, 2018.
[16] A. Hashmi, "Forbes Health," 2022. [Online]. Available: https://www.forbes.com/health/healthy-aging/normal-heart-rate-by-age/ [Accessed 10 July 2022].
[17] Mayo Clinic, "Mayo Clinic," 2018. [Online]. Available: https://www.mayoclinic.org/symptoms/hypoxemia/basics/definition/sym-20050930 [Accessed 10 July 2022].
[18] Cleveland Clinic, "Cleveland Clinic," 2021. [Online]. Available: https://health.clevelandclinic.org/body-temperature-what-is-and-isnt-normal/ [Accessed 10 July 2022].

11 Authors

Bzhar Ghafour Mohammed is an assistant programmer at Salahaddin University, Erbil, Iraq since 2015. He got B.Sc. computer science at Salahaddin University (2014). He is currently M.Sc. student at Salahaddin University, Erbil, Iraq. His research interests are related to IoT and Intelligent Systems (E-mail: bzhar.mohammed@su.edu.krd).

Dr. Dler Salih Hasan is a lecturer at Salahaddin University, Erbil, Iraq since 1999. He got B.Sc. in Production Engineering at University of Technology – Baghdad, Iraq (1991), and he got his M.Sc. in Production Engineering at University of Technology – Baghdad, Iraq (1999). His split-site Ph.D. was in Robotics Engineering (2017 between Salahaddin University, Iraq & University of Florida, USA). He is currently Head of Computer Science & Information Technology Department at Salahaddin University, Erbil, Iraq. His research interests include robotics engineering, sensors and IoT (Email: dler.hasan@su.edu.krd).

Article submitted 2022-08-13. Resubmitted 2022-11-10. Final acceptance 2022-11-23. Final version published as submitted by the authors.