Indonesian Physical Review
Volume 5 Issue 1, January 2022
P-ISSN: 2615-1278, E-ISSN: 2614-7904

Internet of medical things (IoMT)-based heart rate and body temperature monitoring system

Ida Laila[1], A Arifin[1], Bidayatul Armynah[1]
[1]*Departemen of Physics, Faculty of Mathematics and Natural Science, Hasanuddin University, Indonesia*
E-mail: ilapatintingan@gmail.com

ARTICLE INFO

Keywords:
Received: 27–12–2021
Revised: 18-01-2022
Accepted: 23-01-2022

Keywords:
Body Temperature, Heart rate, IoMT, Raspberry Pi, Web Server

How To Cite:
Laila, I., Arifin, A., Armynah, B. (2022). Internet of Medical Things (IoMT)-Based Heart Rate and Body Temperature Monitoring System. Indonesian Physical Review, 5(1), 1-14.

DOI:
https://doi.org/10.29303/ipr.v5i1.134

ABSTRACT
Research has been carried out on a heart rate and body temperature monitoring system based on the Internet of Medical Things (IoMT). This study aims to create a system for monitoring heart rate and body temperature remotely in real-time with measurement results displayed on a web server. This research includes several stages such as developing research concepts based on literature studies, system design consisting of hardware and software design, sensor calibration, web server creation, system testing, and direct data retrieval. The hardware manufacturing stage uses several components such as a pulse heart sensor to detect heart rate, DS18B20 sensor to detect body temperature, Arduino Uno microcontroller, Xbee end device, Xbee coordinator, and raspberry pi as a server computer. Then for the use of software on this system, it consists of Arduino Integrated Development Environment (IDE) to run Arduino Uno hardware, XCTU to provide configuration on Xbee, Python to run Raspberry Pi and Django as a framework for building web servers and MySQL as data storage center measurement results. Heart rate monitoring is done by placing a sensor on one of the fingers, and body temperature is done by placing the sensor in the axilla. The output from the sensor in the form of analog data is converted by the Arduino Uno microcontroller into digital data and then sent to the Raspberry Pi module via Xbee. The raspberry pi has processed data is then stored in the database and then displayed on the webserver. The sensor calibration results show that the pulse heart sensor's error rate is 0.41%, and the DS18B20 temperature sensor is 1.09%. After calibration of the sensor, data was collected on the three respondents' heart rate and body temperature. The measurement results show that the system can store each respondent's heart rate and body temperature data in the database and display the measurement results on the webserver in real-time. Based on these results indicate that the system that has been made can work well.

Introduction

Health is the primary need for every human being to carry out daily activities. Human health conditions can be determined by examining vital signs [1]. Examination of vital signs includes checking heart rate, body temperature, respiration, and blood pressure [2-5]. Monitoring vital signs is the main priority that must be considered by medical personnel to carry out early prevention and reduce mortality [6]. The population in Indonesia continues to grow, but health care and monitoring remain a severe problem. Based on data from the Ministry of Health of the

Republic of Indonesia in 2019, the number of health workers as many as 1,182,024 people is not comparable to the population of 268,074,565 people [7]. This makes the health care system ineffective and inefficient. In addition, the current pandemic condition is also a moderately severe problem. Furthermore, physical distancing makes it difficult for humans to carry out health checks in hospitals [8]. Therefore we need a health monitoring system to check heart rate and body temperature remotely in real-time.

The development of health care and communication network sensors has encouraged the emergence of the Internet of Things (IoT) based on health measurement and monitoring [9,10]. This technology can send data over a network without requiring human-to-human or human-to-computer interaction [11-13]. In its application, IoT can identify, find, track, and can monitor objects remotely automatically and in real-time [14]. IoT technology has been widely applied in various healthcare industry sectors, commonly known as the Internet of Medical Things (IoMT). IoMT is an intelligent platform consisting of sensors and electronic devices used to obtain biomedical signals from patients [15]. These devices consist of processors for processing biomedical signals, network devices for transmitting biomedical data over the network, temporary or permanent storage units, and visualization platforms with artificial intelligence schemes for decision making or diagnosis by doctors [16,17]. IoMT based remote health monitoring system is an alternative that several researchers are currently developing to improve the health care system in hospitals.

Several researchers have carried out research related to remote health monitoring, such as Li et al. (2017), regarding an IoT-based heart disease monitoring system for health services. This system can continuously monitor the patient's physical signs such as blood pressure, ECG, SpO2, heart rate, pulse, blood fat, blood glucose, and environmental indicators (patient position) [18]. Kalamkar et al. (2018) regarding a human health monitoring system using IoT and raspberry pi 3. This system can monitor several parameters such as the electrocardiogram (ECG), blood pressure, heart rate, and body temperature [19]. Zouka and Hosni research (2019) on a health care monitoring system with IoT communication that utilizes a biomedical wireless sensor network. This system uses a microcontroller to communicate with various sensors such as temperature, pulse, and blood pressure sensors [20]. Sheela and Varghese's research (2020) related to a machine learning-based health monitoring system with Arduino Uno control which was then connected to several sensors to detect five measurement parameters in the body, namely (ECG), pulse, blood pressure, body temperature, and patient position [21]. Shewale and Sankpal (2020) researched IoT-based health care systems by measuring several parameters such as heart rate, body temperature, and blood pressure [22]. Some of the studies above have weaknesses, such as transmitting data from the microcontroller to the raspberry pi still using Bluetooth communication and some researchers testing the patient health monitoring system based on simulations to determine the performance of the IoT system. Therefore, in this research, the IoMT-based heart rate and body temperature monitoring system using a raspberry pi as a computer server and transmitting data from the microcontroller to a raspberry pi using Xbee communication, then testing the system using several devices that have been integrated with sensors that can detect heart rate and body temperature parameters in humans (objects). The measurement data is then saved to the database and displayed on the webserver in real-time. This system is expected to accelerate the diagnosis of patient disease, reduce the workload of medical personnel and reduce operational costs.

Experimental Method

This research includes several stages such as developing research concepts based on literature studies, system design consisting of hardware and software design, sensor calibration to see comparisons of sensor measurement results with comparison measuring instruments, web server creation, system testing, and direct data retrieval.

System Design

The design of the IoMT based heart rate and body temperature monitoring system consists of two stages, namely hardware and software design. The hardware design stage uses several components such as pulse heart sensor, body temperature sensor, Arduino Uno microcontroller, Xbee end device, Xbee coordinator, and raspberry pi as a server computer. Then, the use of software on this system consists of the Arduino IDE to compile and upload Arduino Uno hardware, XCTU to provide configuration on Xbee, Python, and Django-framework to run Raspberry Pi and MySQL database as a data storage center. The additional software used to build a web server such as atom as a python text editor and PuTTY as a terminal emulator to access the server remotely. Figure 1 shows a block diagram of an IoMT based heart rate and body temperature monitoring system.

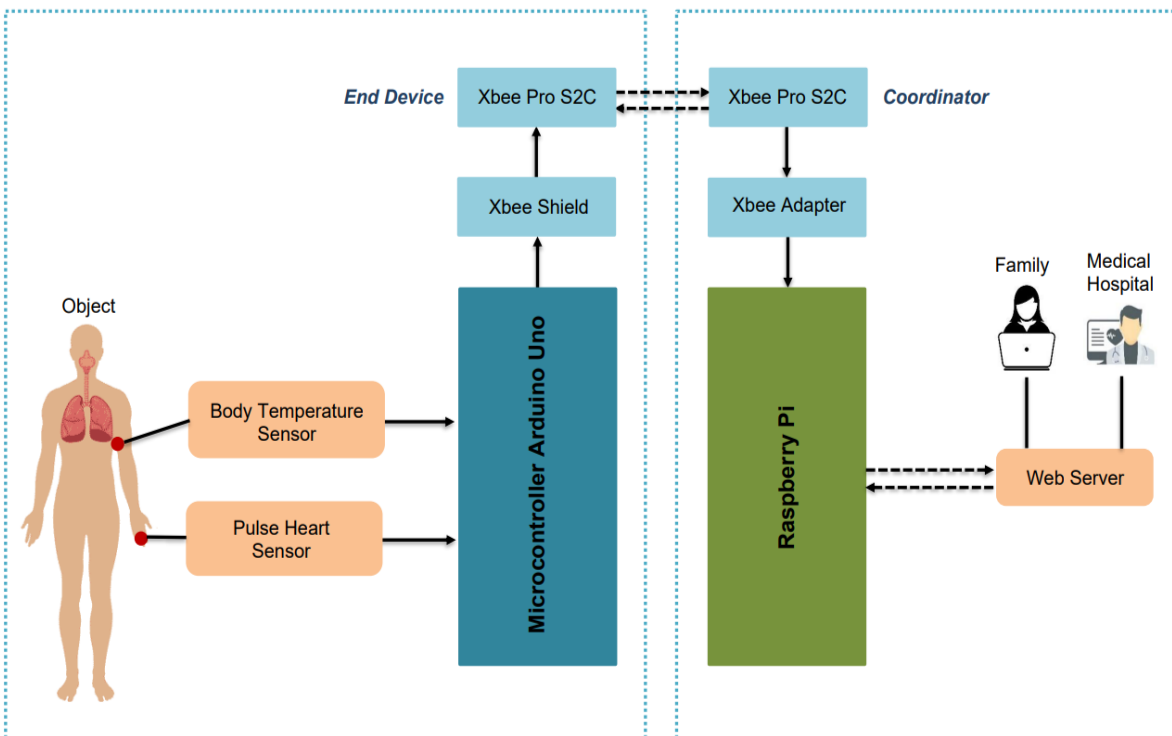


Figure 1. Block diagram of an IoMT based heart rate and body temperature monitoring system

The block diagram above shows an IoMT-based heart rate and body temperature monitoring system. Two sensor kits are used to detect each parameter, such as body temperature and respiration in the human body. This sensor is controlled by the Arduino Uno microcontroller, which functions as a processor for inputting data from sensors mounted on the body. First, a program was created using Arduino IDE to read the sensor measurement data. The Arduino

Uno microcontroller has processed data is then sent to the raspberry pi via Xbee as wireless data communication. But first, the Xbee configuration is done using the XCTU software. The configuration provides ID and sets the Xbee function, Xbee end devices, and Xbee coordinators. The measurement data sent via Xbee is then processed by the raspberry pi using python software which then the results will be stored in a database and can be displayed on the webserver in real-time. Medical personnel and the patient's family can access the measurement results through the website. The hardware design of the IoMT based heart rate and body temperature monitoring system is shown in Figure 2.

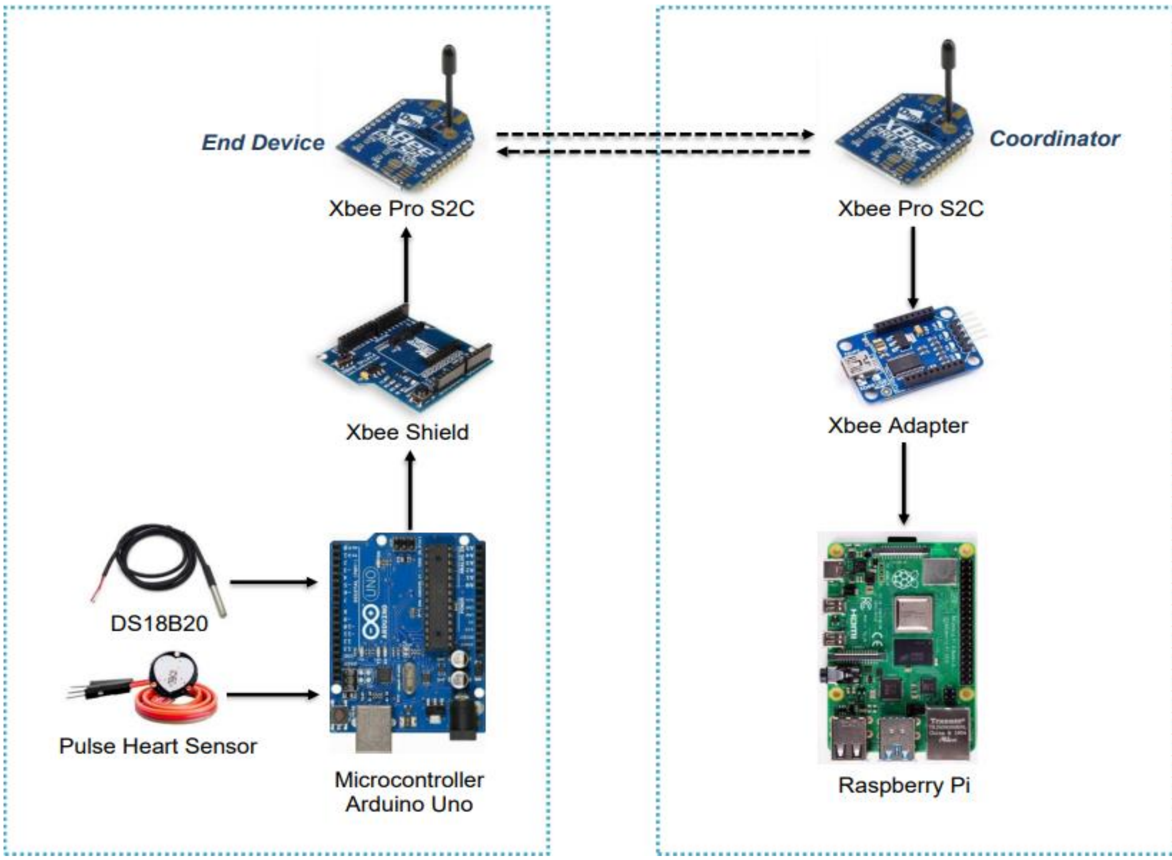


Figure 2. Hardware design of IoMT based heart rate and body temperature monitoring system

Sensor Calibration

In this study, the heart rate and body temperature sensors were calibrated to reduce the measurement error value for each sensor. The heart rate sensor calibration process is carried out by comparing the results of the heart rate calculation using a pulse heart sensor placed on the finger with a comparison tool in the form of a pulse oximeter measured simultaneously. The heart rate sensor calibration data retrieval was carried out for 5 minutes with a measurement time delay of 3 seconds so that the data obtained was 100 data. At the same time, the temperature sensor calibration process is carried out by comparing the results of temperature calculations using the DS18B20 temperature sensor with a comparison tool in the form of a thermometer.

Web Server Design

The first step in making a web server is to install the operating system on raspberry pi. The raspberry pi operating system that is currently widely recommended is raspbian. After installing the operating system on the raspberry pi is successful, the next step is to download the python and Django-framework software on the raspberry pi. Then the next step is to create a web server using the Django-framework. Several programming languages are used in making web servers, such as Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, and databases. Applications on the web are divided into static and dynamic web applications. HTML is used to create a static website, JavaScript to create a dynamic website, CSS to adjust the website's appearance to make it look attractive and structured. The database used is MySQL which acts as central storage for sensor measurement data obtained before being sent to the webserver. The process of sending sensor measurement data to the webserver uses two-way communication with JavaScript Object Notation (JSON) data format, and the webserver dashboard display uses one-way communication by applying Server-Sent Event (SSE) rules. The web server workflow is shown in Figure 3.

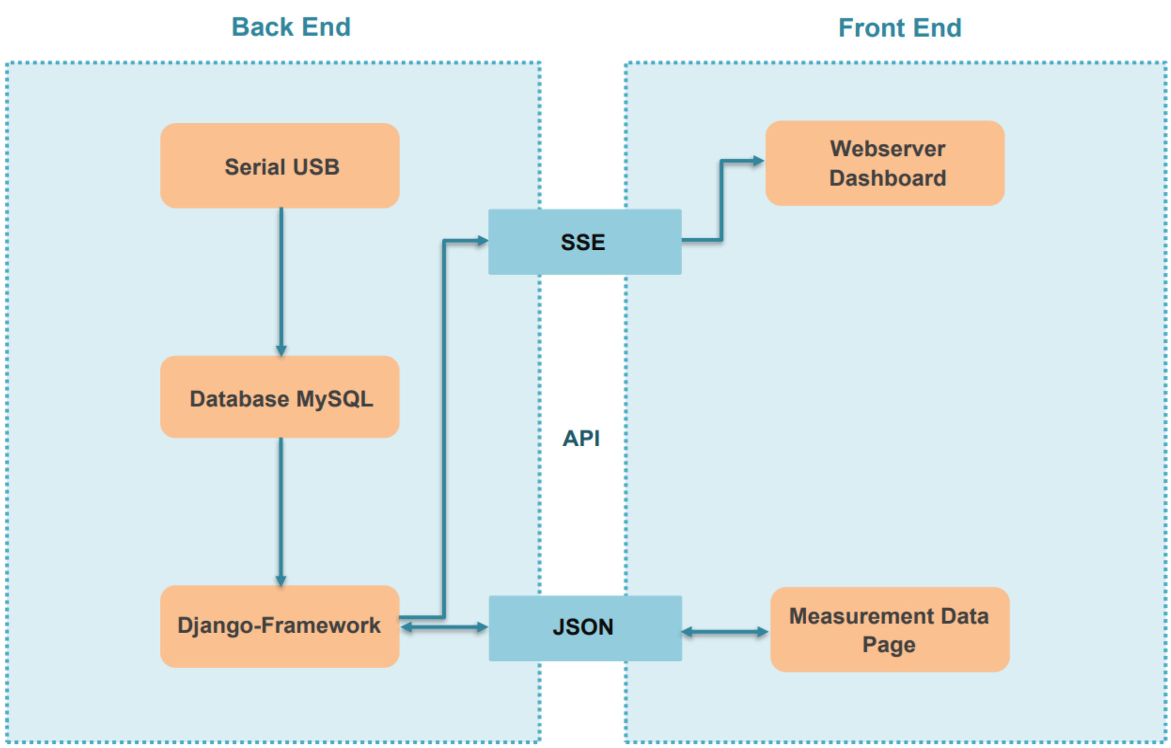


Figure 3. Web server workflow

System Testing and Measurement

System testing is done after system design and web server creation. This test is carried out to see the success of the system made. Testing the heart rate sensor and body temperature sensor begins with the preparation of measurement instruments and verification of the Arduino IDE program for further testing. The first test is the heart rate sensor which is done by placing the sensor on one fingertip. After that, whether the sensor can record heart rate data and display the value of beats per minute (bpm) on the webserver is observed. Fingertip selection and placement of sensors result in more consistent and stable data. Heart rate data varies according to the patient's condition at measurement. The second test is the DS18B20 temperature sensor, which is carried out by placing the sensor in the armpit and observing changes in temperature on the webserver in degrees Celsius. Body temperature data will vary according to the patient's physical condition and the ambient temperature at data collection.

Result and Discussion

Sensor Calibration Results

In this study, the pulse heart sensor and the DS18B20 temperature sensor were calibrated to see the error rate for each sensor. The test compares the sensor measurement results with a comparison tool. The error value for each sensor is obtained by using equation (1) [23]:

$$RE = \frac{F - F_a}{F_a} \times 100\% \quad (1)$$

Where RE is the error percentage, F is the sensor measurement value, and F_a is the comparison tool measurement value. The graph of the comparison of the results of heart rate measurements using a pulse heart sensor with a comparison measuring instrument in the form of an oximeter is shown in Figure 4.

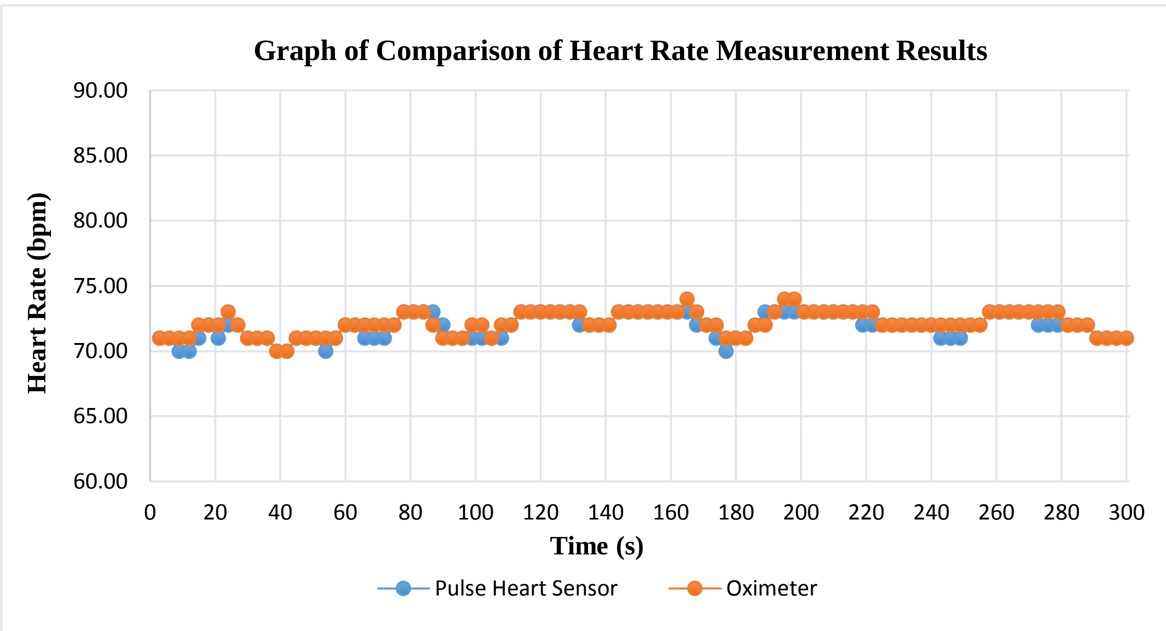


Figure 4. Comparison graph of heart rate measurement results

The graph above shows the results of measuring heart rate in one respondent who is 23 years old. Heart rate measurements were carried out in a resting condition with a measurement time of 5 minutes and a delay of 3 seconds. The test results show the heart rate is at 70 bpm to 74 bpm with an error rate of 0.41%. The results obtained are by previous research conducted by Alamsyah, et al. (2020), which states that a normal heart rate at rest is in the range of 60 bpm to 100 bpm [6]. Furthermore, the comparison of the temperature measurement results is shown in Figure 5.

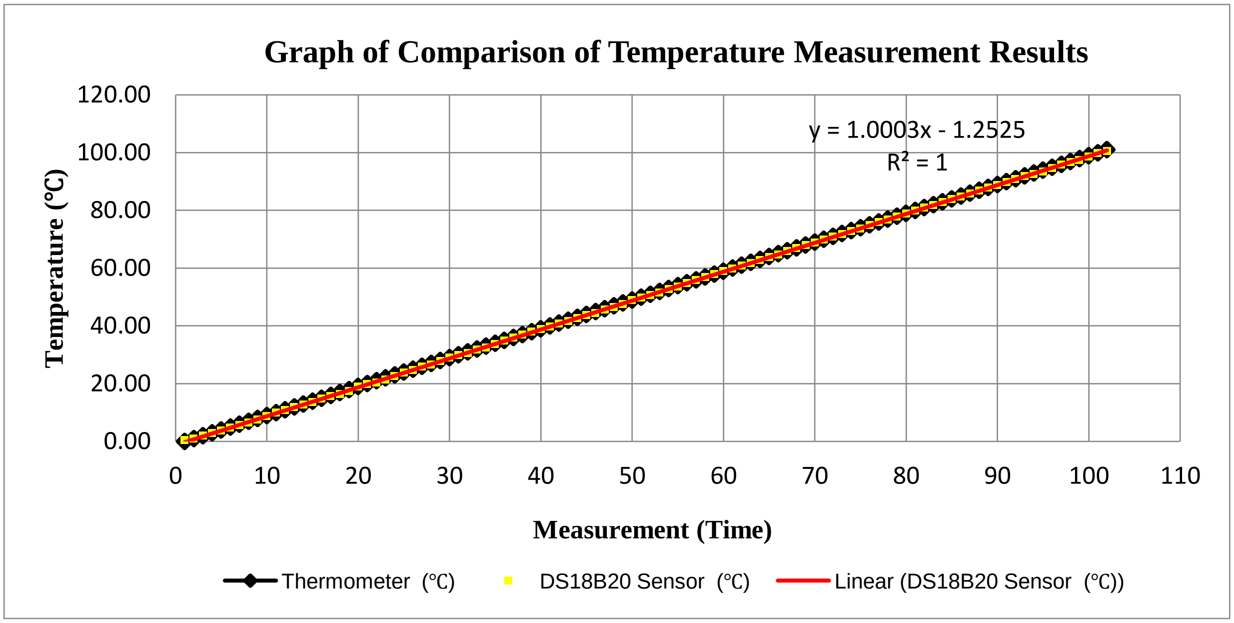


Figure 5. Comparison graph of temperature measurement results

The graph above shows the results of temperature measurements using the DS18B20 temperature sensor with a comparison tool in a thermometer. The measurement results obtained an error rate of 1.09% from the measurement range 0°C to 100°C.

System Test Results

The Internet of Medical Things (IoMT) based heart rate and body temperature monitoring system has worked well. The results of heart rate and body temperature measurements are stored in a database and then displayed on a web server in the form of graphs or tables.

a. Heart Rate Measurement

Heart rate measurements were carried out twice. The first measurement was carried out on one respondent aged 23 years with different measurement times, namely in the morning, noon and afternoon. The second measurement was on three respondents aged 23 years, namely in the morning, with the same measurement time. Figure 6 shows the heart rate measurements in one respondent with different measurement times.

Figure 6 shows the results of measuring heart rate per minute in one respondent in a resting (normal) condition. The average heart rate in the morning is 77.20 bpm, 81.50 bpm in the noon, and 79.33 bpm in the afternoon. Based on the results obtained, it can be concluded that the system can measure heart rate well with the measurement results following previous research conducted by Ahammed, et al. (2021). His research stated that the normal heart rate of adults in resting conditions ranges from 60 bpm to 100 bpm [24]. Furthermore, the results of heart rate measurements in three respondents are shown in Figure 7.

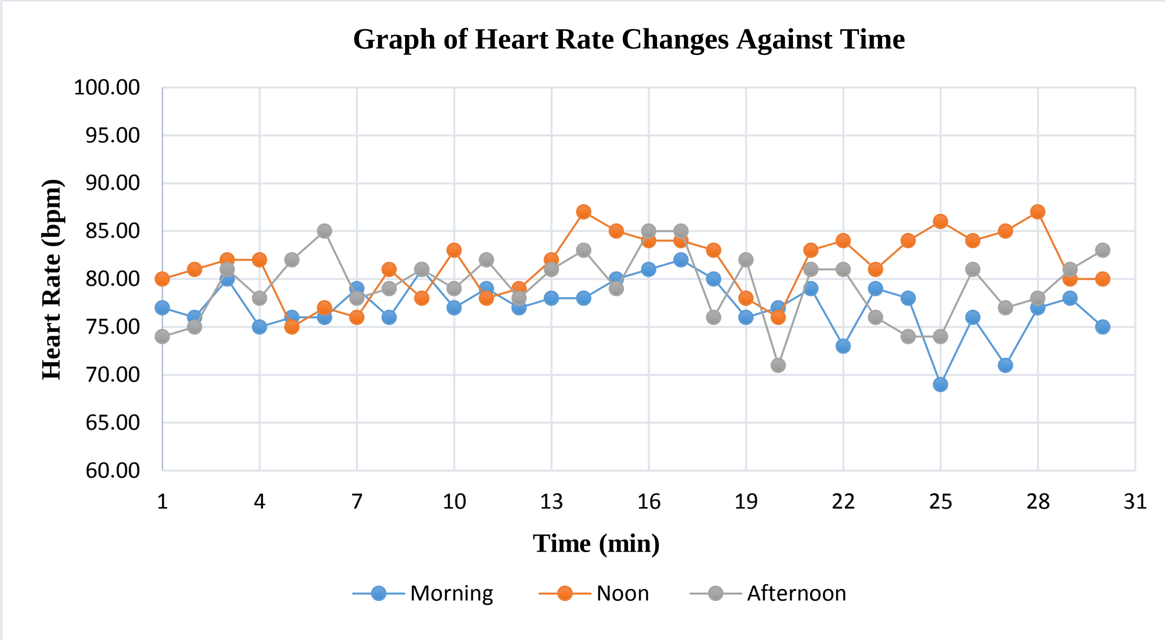


Figure 6. Graph of heart rate measurement results in one respondent

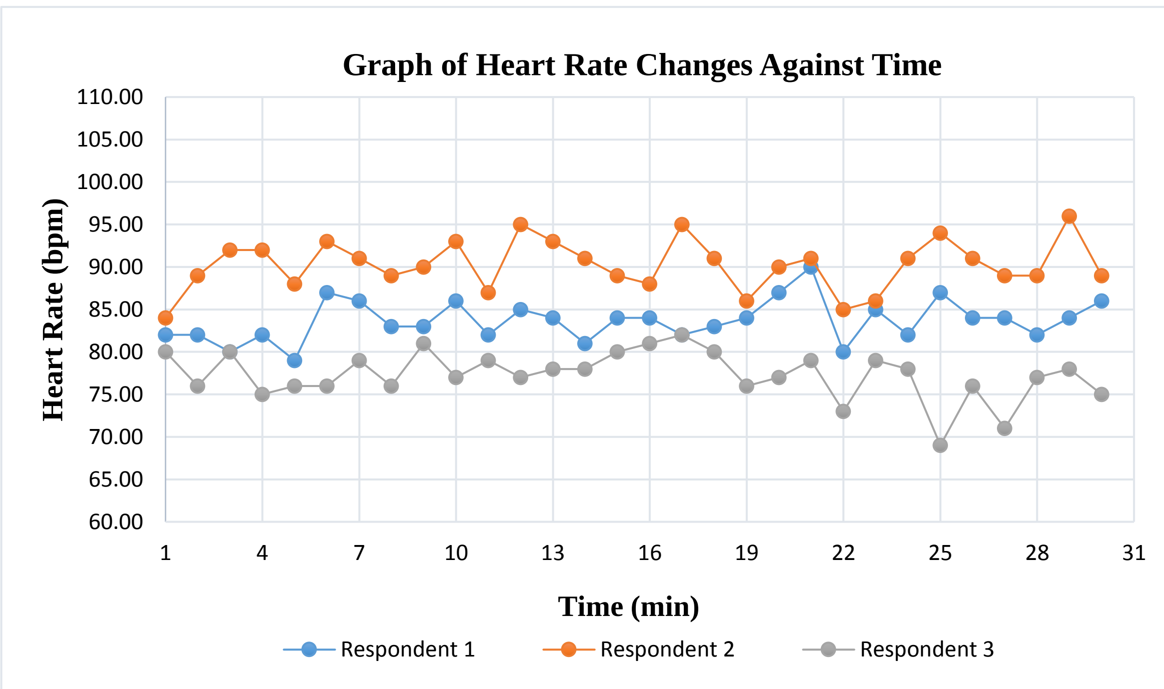


Figure 7. Graph of heart rate measurement results for three respondents

Figure 7 shows the heart rate per minute for three respondents in a resting condition. The measurement results show that the average heart rate of each respondent is 83.67 bpm, 90.23 bpm, and 77.30 bpm, respectively. The measurement results indicate that the heart rates of the three respondents are in the normal category.

b. Body Temperature Measurement

Body temperature measurement is done to analyze the patient's body temperature condition. The first measurement was carried out on one respondent with different measurement times, namely in the morning, noon and afternoon. The second measurement on three respondents with the same measurement time is in the morning. The results of measuring body temperature in one respondent at different times are shown in Figure 8.

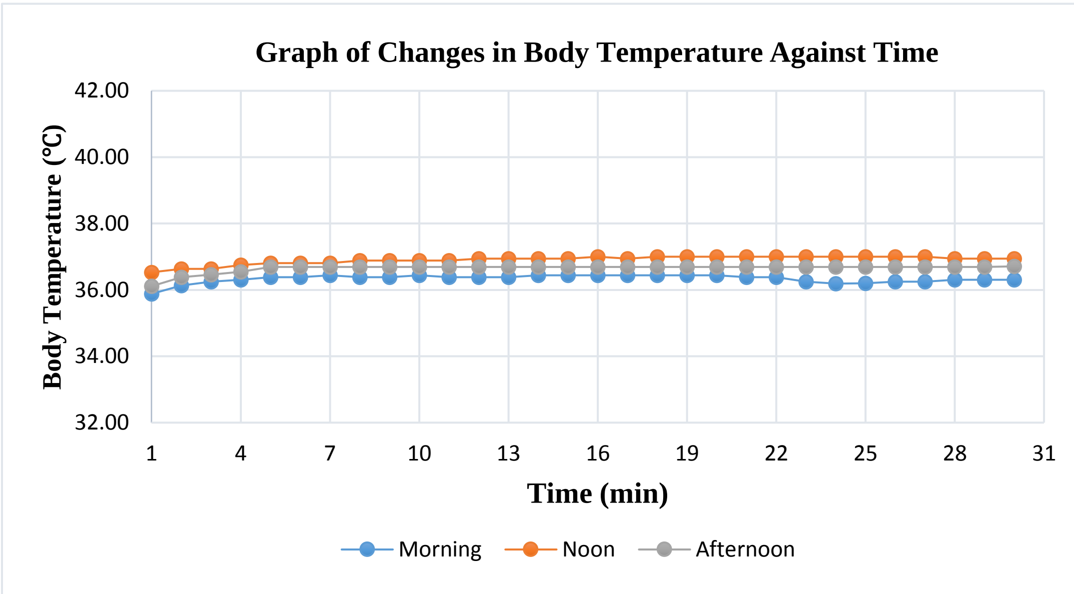


Figure 8. Graph of body temperature measurement results in one respondent

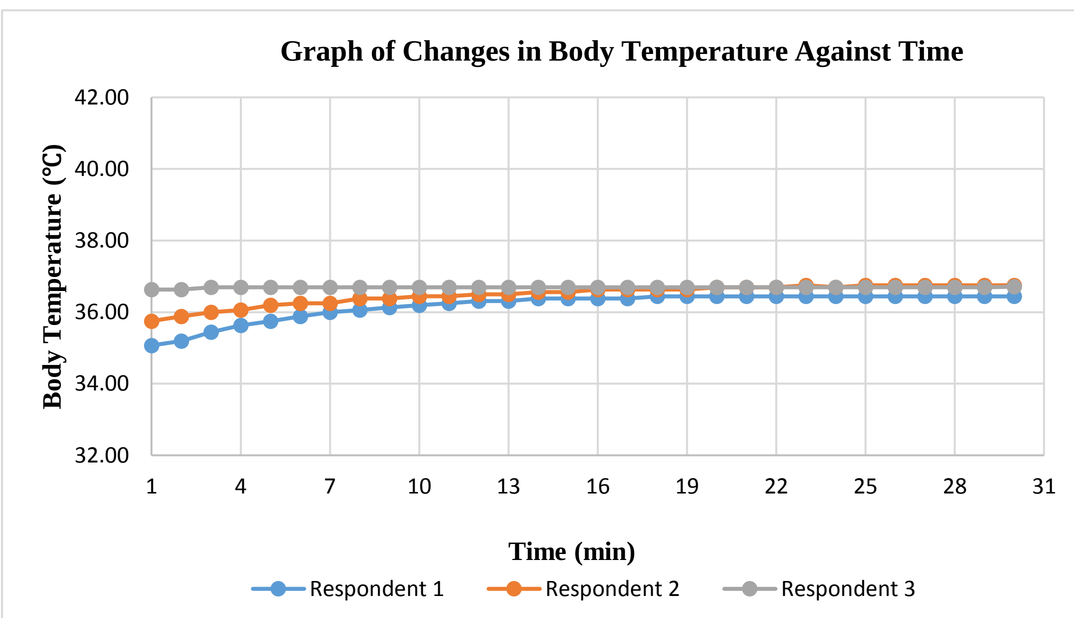


Figure 9. Graph of body temperature measurement results for three respondents

Figure 8 shows the body temperature per minute for one respondent with three measurements at different times. The measurement results show that the average body temperature in the morning is 36.33℃, noonday 36.90℃, and in the afternoon 36.65℃. The results obtained show that the respondent's body temperature is still in the normal category, with a temperature range of 36.33°C to 36.90°C. This is following the standards of the World Health Organization (WHO), where the average human body temperature ranges from 36°C to 38°C [25]. From the measurement results, it can be seen that body temperature noonday is higher than body temperature in the morning and afternoon. Differences in temperature measurement results are caused by several factors such as ambient temperature and the respondent's activities before taking measurements. Furthermore, the measurement of body temperature in three respondents in the morning is shown in Figure 9.

Figure 9 shows the body temperature results in three respondents who were measured in the morning. The measurement results show that the average body temperature of each respondent is 36.18°C, 36.49°C, and 36.69°C, respectively. Therefore, based on the measurement results, each respondent's body temperature is in average condition.

Display of Measurement Results on the Web Server

The heart rate and body temperature monitoring system on the webserver consists of several pages, namely dashboard (home), patient data, patient history, medical records, and monitoring. First, the measurement results of heart rate and body temperature are displayed on the patient history page with a display in data graphs and data tables. Then the display of measurement results in real-time is located on the medical record page. The dashboard view of the system is shown in Figure 10.

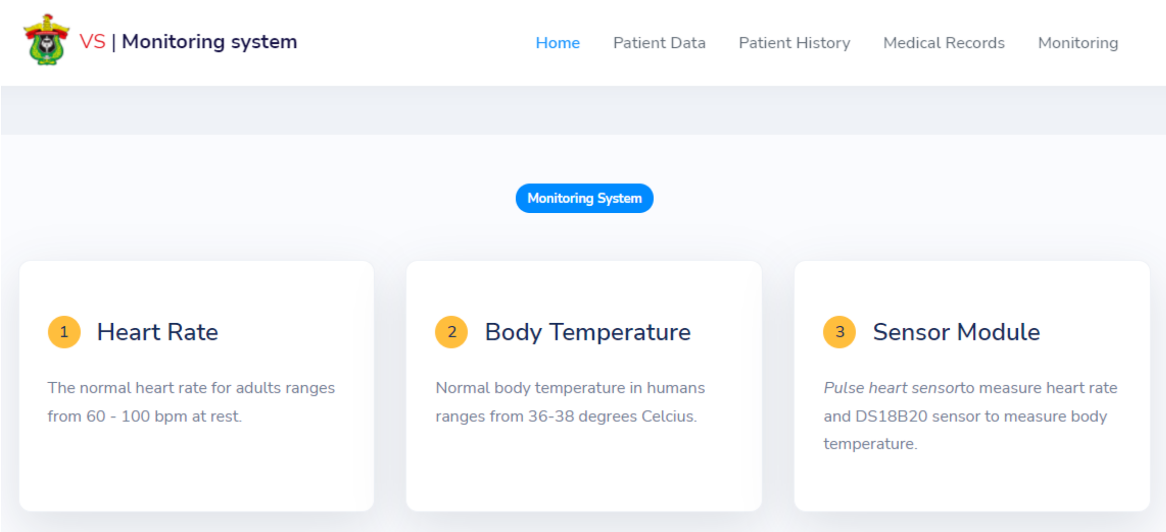
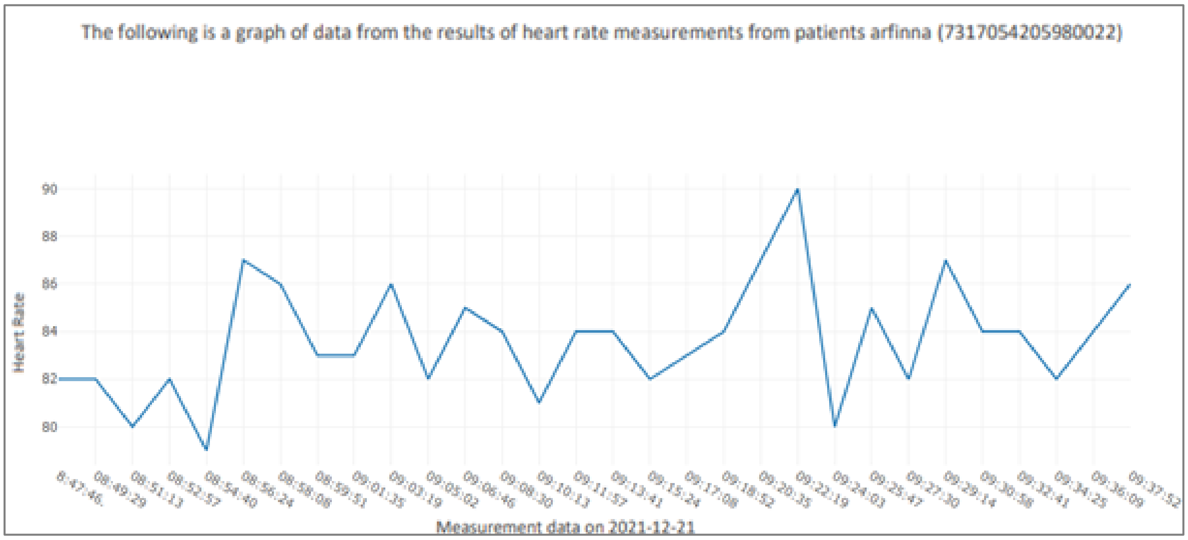
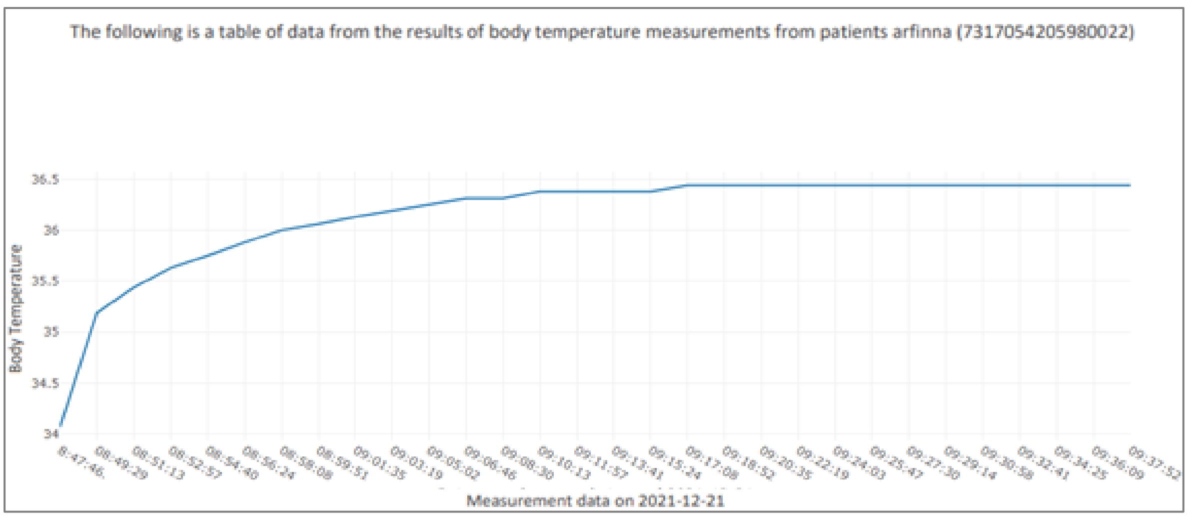


Figure 10. Dashboard display of IoMT based heart rate and body temperature monitoring system

The figure above shows a web server dashboard display on a heart rate and body temperature monitoring system. This page contains information about the average human heart rate and body temperature and the use of the types of sensors used in this study. Furthermore, the graphic display of the data from the measurement of heart rate and body temperature on the webserver is shown in Figure 11. Figure 12 is a table display of data from the heart rate and body temperature measurement on the web server.



(a)



(b)

Figure 11. Graph display of data on a web server (a) heart rate; (b) body temperature

The following is a table of data from the results of heart rate measurements from patients arfinna (7317054205980022)

Time	Heart Rate
'2021-12-21 08:47:46.075375+00:00'	82.0
'2021-12-21 08:49:29.756372+00:00'	82.0
'2021-12-21 08:51:13.407562+00:00'	83.0
'2021-12-21 08:52:57.092468+00:00'	82.0
'2021-12-21 08:54:40.758967+00:00'	79.0
'2021-12-21 08:56:24.693227+00:00'	87.0
'2021-12-21 08:58:08.106941+00:00'	86.0
'2021-12-21 08:59:51.791025+00:00'	83.0
'2021-12-21 09:01:35.473119+00:00'	83.0
'2021-12-21 09:03:19.147299+00:00'	86.0

(a)

The following is a table of data from the results of body temperature measurements from patients arfinna (7317054205980022)

Time	Body Temperature
'2021-12-21 08:47:46.075375+00:00'	34.07
'2021-12-21 08:49:29.756372+00:00'	35.19
'2021-12-21 08:51:13.407562+00:00'	35.44
'2021-12-21 08:52:57.092468+00:00'	35.63
'2021-12-21 08:54:40.758967+00:00'	35.75
'2021-12-21 08:56:24.693227+00:00'	35.88
'2021-12-21 08:58:08.106941+00:00'	36.0
'2021-12-21 08:59:51.791025+00:00'	36.06
'2021-12-21 09:01:35.473119+00:00'	36.13
'2021-12-21 09:03:19.147299+00:00'	36.19

(b)

Figure 12. Table display of data on a web server (a) heart rate; (b) body temperature

Conclusion

Research on the Internet of Medical Things (IoMT) based on heart rate and body temperature monitoring systems has been successfully conducted. This system can monitor heart rate and body temperature remotely by displaying measurement data on a web server. The sensor calibration results show the pulse heart sensor's error rate is 0.41%, and the DS18B20 temperature sensor is 1.09%. After calibration of the sensor, data was collected on the three respondents' heart rate and body temperature. The measurement results show that the system can store each respondent's heart rate and body temperature data in the database and display the measurement results on the webserver in real-time. Based on these results indicate that the system that has been made can work well.

References

[1] S. Vishnu, S. R. J. Ramson, R. Jegan (2020). Internet of medical things (IoMT). *International Conference on Devices Circuits and Systems (ICDCS)* 101-104. Doi: https://doi.org/10.1109/ICDCS48716.2020.243558

[2] P. S. Akram, S. A. S. Valiveti, M. Ramesha, S. Sohail, K. T. S. S. Rao (2021). IoT based remote patient health monitoring system. *7th International Converence on Advanced Computing & Communication System (ICACCS)* 978-1-6654-0521-8/20/$31.00. Doi: https://doi.org/10.1109/ICACCS51430.2021.9441874

[3] D. Gupta, A. Parikh, R. Swarnalatha (2020). Integrated healthcare monitoring device for obese adults using internet of things (IoT). *International Journal of Electrical and Computer Engineering (IJECE)* 10 (1) 1239-1247. Doi: https://doi.org/10.11591/ijece.v10i1.pp1239-1247

[4] I. D. G. H. Wisana, B. Utomo, F. Amrinsani, E. Purwanto (2021). Low coast health monitoring system based on internet of things using email notification. *International Journal of Electronics, Electromedical, and Medical Informatics (IJEEEMI)* 3 (2) 45-52. Doi: https://doi.org/10. 35882/ijeeemi.v3i2.2

[5] K. T. Kadhim, A. M. Alsahlany, S. M Wadi, H. T. Kadhum (2020). Monitoring vital signs of human hear based on IOT 1 (2) 9-13. Doi: https://doi.org/10.46649/110420-0.

[6] Alamsyah, M. Subito, M. Ikhlayel, E. Setijadi (2020). Internet of things based vital sign monitoring system. *International Journal of Electrical and Computer Engineering (IJECE)* 10 (6) 5891-5898. Doi: https://doi.org/10.11591/ijece.v10i6.pp5891-5898

[7] B. Hardhana, F. Sibuea, W. Widiantini. (2020). Profil Kesehatan Indonesia Tahun 2019. Jakarta: Kementrian Kesehatan Republik Indonesia.

[8] S. S. Vedaei, A. Fotovvat, M. R. Mohebbian, G. M. E. Rahman, K. A. Wahid, P. Babyn, H. R. Marateb, M. Mansourian, R. Sami (2020). Covid safe an IoT based system for automated health monitoring and surveyllace in post pandemic life. *IEEE* 20 1-13. Doi: https://doi.org/10.1109/ACCESS.2020.3030194

[9] J. Jusjak, I. Puspasari, W. I. Kusumawati (2021). A Semi-automatic Heart Sounds Identification Model and Its Implementation in Internet of Things. *Advances in Electrical and Computer Engineering* 21 (1) 45-56. Doi: https://doi.org/10.4316/AECE.2021.01005

[10] T. Wang, L. Qiu, A. K. Sangaiah, A. Liu, M. Z. A. Bhuiyan, Y. Ma (2019). Edge Computing Based Trustworthy Data Collection Model in the Internet of Things. *Journal of Latex Class Files* 20 (20) 1-10. Doi: https://doi.org/10.1109/JIOT.2020.2966870

[11] M. Stoyanova, Y. Nikoloudakis, S. Panagiotakis, E. Pallis, E. K. Markakis (2020). A Survey on the Internet of Things Forensics: Challenges, Approaches, and Open Issue. *IEEE Communication Surveys & Tutorials* 22 (2) 1191-1221. doi: https://doi.org/10.1109/COMST.2019.2962586

[12] D. A. Hasan and A. G. Ismaeel (2020). Designing ECG monitoring healthcare system based on internet of things blynk application. *Journal of Applied Science and Technology Trends* 1 (3) 106-111. Doi: https://doi.org/10.38094/jastt1336

[13] S. Hadiyoso, A. Alfaruq, R. Tulloh, Y. S. Rohmah, E. Susanto (2021). Internet of things based real-time vital sign monitoring system using mobile application. *Journal of Applied Engineering Science* 3 (19) 807-813. Doi: https://doi.org/10.5937/jaes0-28774

[14] P. K. Malik, R. Sharma, R. Singh, A. Gehlot, S. C. Satapathy, W. S. Alnumay, D. Pelusi, U. Ghosh, J. Nayak (2020). Industrial Internet of Things and its applications in industry 4.0:

State of the art. *Computer Communications*. Doi: https://doi.org/10.1016/j.comcom.2020.11.016

[15] S. A. Chaudhry, A. Irshad, J. Nebhen, A. K. Bashir, N. Moustafa, Y. D. Al-Otaibi, Y. B. Zikria (2021). An anonymous device to device access control based on secure certificate for internet of medical things systems. *Sustainable Cities and Society 75 103322*. Doi: https://doi.org/10.1016/j.scs.2021.103322

[16] N. H. Motlagh, M. Mohammadrezaei, J. Hunt, B. Zakeri (2020). Internet of things (IoT) and the energy sector. *Journal Energies* 13 (494) 1-27. Doi: https://doi.org/10.3390/en13020494

[17] R. P. Singh, M. Javaid, A. Haleem, R. Vaishya, S. Ali (2020). Internet of medical things (IoMT) for orthopaedic in COVID-19 pandemic: Roles, challenges, and applications. *Journal of Clinical Orthopaedics and Trauma*. Doi: https://doi.org/10.1016/j.scs.2021.103322

[18] C. Li, X. Hu, L. Zhang (2017). The IoT-based Heart Disease Monitoring System for Pervasive Healthcare Service. *Procedia Computer Science* (112) 2328-2334. Doi: https://doi.org/10.1016/j.procs.2017.08.265

[19] P. Kalamkar, P. Patil, T. Bhongale, M. Kamble (2018). Human Health Monitoring System using IoT and Raspberry Pi. *International Research Journal of Engineering and Technology* 5 (3) 3551-3553. Doi: https://doi.org/10.1109/ICIMIA.2017.7975587

[20] H. A. E. Zouka and M. M. Hosni (2019). Secure IoT communications for smart healthcare monitoring system. *Journal Internet of Things* 2542-6605 1-14. Doi: https://doi.org/10.1016/j.iot.2019.01.003

[21] G. Sheela and A. R. Varghese (2020). Machine Learning based Health Monitoring System. *Proceedings Materials* 24 1788-1794. Doi: https://doi.org/10.1016/j.matpr.2020.03.603

[22] A. D. Shewale and S. V. Sankpal (2020). IOT & Raspberry Pi based Smart and Secure Health Care System using BSN. *International Journal for Research in Applied Science & Engineering Technology* 8 (2) 506-510.

[23] Y. Li, J. Li, J. Huang, H. Zou (2020). Fitting analysis and research of measured data of SAW micro-pressure sensor based on BP neural network. *Measurement* 155 107533 1-6. Doi: https://doi.org/10.1016/j.measurement.2020.107533

[24] S. Ahammed, N. Hassan, S. H. Cheragee, A. Z. M. T. Islam (2021). An iot-based real-time remote health monitoring system. *International Journal of Research Engineering Science* 8 (3) 23-29. Doi: https://doi.org/10.14445/23497157/IJRES-V8I3P104

[25] World Healt Organization. (2011). Integrated Management of Adolescent and Adult Illness (IMAI) Discrit Clinical Manual: Hospital Care for Adolescents and Adults Volume 1. Switzerland: WHO Press.