SJST
sjst.scst.edu.ly
Surman **J**ournal for **S**cience and **T**echnology
ISSN: Online (2790-5721) - Print (2790-5713)
مجلة صرمان للعلوم والتقنية
Vol **7**, No.1.Jan – Jun. 2025
Pages: 129 ~ 144

IoT-Based Patient Health Monitoring System Using NodeMCU

[1]Najat Boufa, [2]Husam Khaleel, [3]Al-Muetaz Abou Khadeer, [4]Ali Nasrat
Faculty of Medical Technology, University of Zawia, Libya[1,2,3,4]
Email: [1]n.boufa@zu.edu.ly, [2] khlilhossam8@gmail.com, [3]motaz1556@gmail.com

ABSTRACT

Purpose: The integration of the Internet of Things (IoT) in health monitoring systems represents a significant advancement in the medical field, particularly for remote patient health monitoring. By connecting sensors to the internet, a patient's vital signs can be measured remotely. This study aimed to design a simple, accurate, and low-cost IoT-based system to monitor vital signs such as body temperature, pulse rate, oxygen saturation level (SpO_2), and room conditions. **Materials and Methods:** The monitoring system comprises two NodeMCU ESP8266 development boards, serving as the main microcontrollers with integrated Wi-Fi capabilities. The system utilizes the DS18B20 sensor for body temperature, the MAX30102 sensor for pulse rate and SpO_2, and the DHT11 sensor for room conditions. These sensors collect data and transmit it to the NodeMCU ESP8266 for processing and forwarding to a web application. The system can log the measured data, display it in a historical format, and archive it. The output is accessible on the user's mobile phone, laptop, and LCD screen. Additionally, doctors and caregivers can easily access this data via the website. **Results:** The proposed monitoring system was tested on six male patients from Al-Zawia Hospital. Its readings were compared to those obtained from hospital devices. The pulse rate readings ranged from 76 bpm to 92 bpm, with an average absolute error of 0.4%. SpO_2 readings were between 94% and 97%, with an average absolute error of 2.2%. Body temperature measurements varied between 36.38°C end 37°C, with an error rate of 0.4%. Additionally, the average room temperature and humidity were recorded at 22.01°C and 37.3%, respectively. **Conclusion:** Comparative analysis between the data obtained from the proposed system and conventional devices showed a success

rate of over 95% for almost all measurements. This indicates that the model is effective, accurate, easy to use, and capable of remotely measuring and monitoring a patient's health.

Keywords: Healthcare monitoring system, IoT, NodeMCU ESP8266, Sensors, Vital signs.

Submitted: 02/02/2025 *Accepted: 28/02/2025*

1. Introduction

The rapid development of wireless communication technology has significantly advanced medical technology, enhancing electronic healthcare through the design of low-cost, intelligent, and lightweight sensors that can be strategically placed on the human body. These sensors collect medical data and transmit it via the Internet [1,2]. Remote patient monitoring technology is crucial for both doctors and patients. It allows doctors to remotely monitor and treat patients who are not in hospitals but require continuous monitoring of their vital signs, particularly those with chronic diseases [3,4]. With the rise in chronic diseases and infectious diseases, along with concerns about infection transmission in hospitals, the need for devices that can remotely monitor vital signs has become an essential component of electronic healthcare systems. IoT technologies have facilitated advancements in healthcare, enabling health specialists in clinics to access patients' vital signs on computers or mobile devices [5]. IoT-based real-time health monitoring systems can measure, monitor, and report health status both online and offline from anywhere, while also establishing historical health records for patients [6]. The implementation of IoT in health monitoring systems has made life easier for elderly patients, those with chronic diseases, and individuals living in remote areas. These patients can obtain their vital signs and share the data with their doctors via the internet. In emergencies, IoT-based health monitoring systems can send alert messages to doctors if any parameter becomes abnormal [7]. Vital signs are an important element of patient health monitoring, serving as indicators of a patient's health status and aiding in the detection of medical problems.

Vital signs include measurements of the body's most important functions: body temperature, pulse rate, oxygen saturation, respiration rate and blood pressure. Therefore, an integrated device designed to monitor patient health using IoT is necessary. This involves connecting computers or mobile phones to the internet using microcontrollers and biomedical sensors, such as temperature and pulse rate sensors. This technique allows for patient monitoring outside traditional clinical setting, enabling doctors to monitor patients' health from anywhere. It is a safe and effective solution for patients who cannot visit the doctor, especially during pandemics.

2. Related Works

Various designs of patient health monitoring systems have been developed by researchers in line with technological advancements. Gregoski et al. proposed a smartphone-based heart rate monitoring system that used a mobile light and camera to track blood flow through a fingertip, calculating cardiac output based on this flow. This system wirelessly transfers a person’s pulse to a computer, enabling heart rate measurement by simply looking at the phone instead of using hands each time [8]. A study in [9] designed a wireless monitoring system using Arduino, connected to a laptop via Bluetooth to transmit data. This data was sensed through the Heart Rate Grove sensor and LM35 temperature sensor. Researchers in [7] also proposed an IoT-based patient monitoring system to remotely monitor various vital signs of ICU patients and control medicine dosages. This system, created using a NodeMCU, two Arduinos, and sensors, can send alert messages to doctors in emergencies if any vital signs become abnormal. Islam et al. developed a healthcare system using ESP32 that connected to sensors to capture patient data and environmental factors in the hospital room. The data is displayed on an IoT-based website [10]. Abed and Hussein designed a monitoring device capable of collecting medical data from patients, such as heart rate, oxygen saturation level, and body temperature, and then transmitting the data via the Internet to doctors for health assessment [11]. Khan et al. presented an IoT-based health monitoring system using Arduino, particularly for COVID-19 patients. The system measures a patient's body temperature, heartbeat, and SpO2 levels, sending the data to a mobile application via Bluetooth as well as the IoT [12].

3. Material and Methodology

The proposed health monitoring system utilizes two NodeMCU ESP8266 modules labelled (A and B) connected to specific sensors and LCDs to remotely monitor patient parameters. NodeMCU ESP8266 (A) is connected to the DS18B20 sensor and sends data to a 16×2 LCD. NodeMCU ESP8266 (B) is connected to the DHT11 and MAX30102 sensors and sends data to a 20×4 LCD. Both units transmit measured data for remote viewing via a laptop or mobile app.

The block diagram in (Figure 1), circuit schematic in (Figure 2), and prototype photo in (Figure 3) provide a comprehensive overview of the system setup and implementation. The proposed health monitoring system integrates two major components: hardware and software.

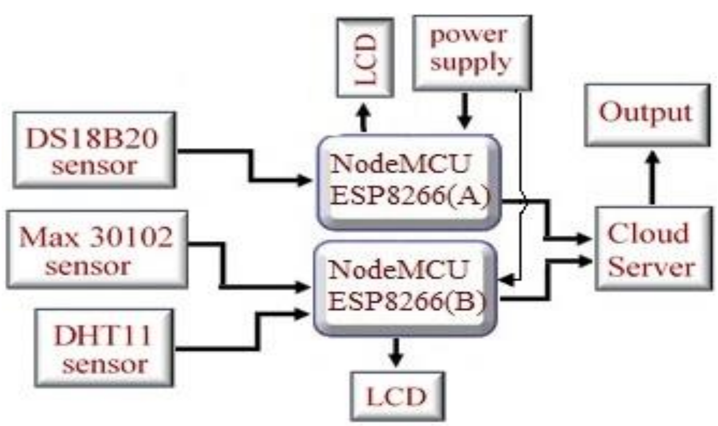

Figure 1. Block diagram of the health monitoring system

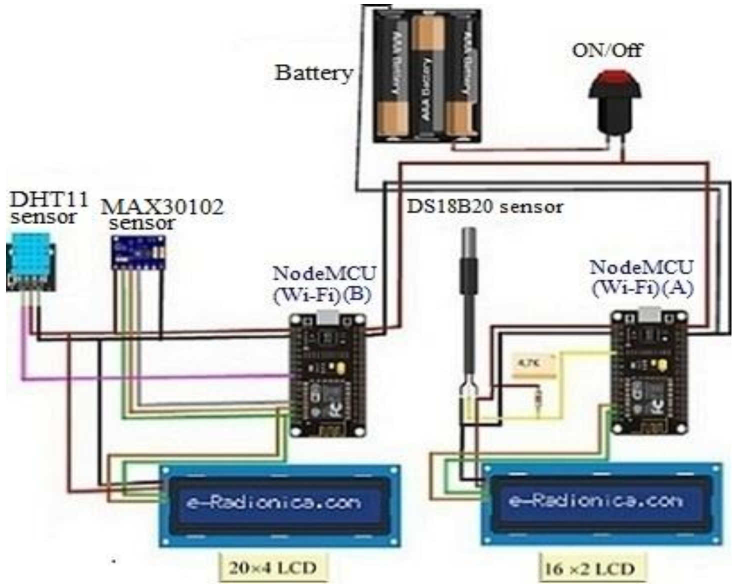

Fig 2. Schematic circuit of the proposed system

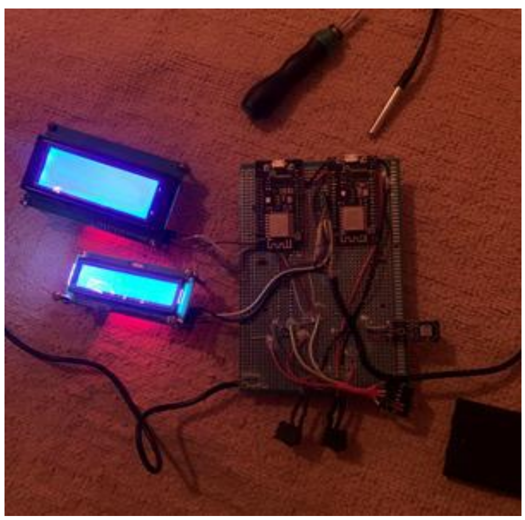

Figure 3. Prototype of the health monitoring system

3.1. Hardware Equipment

The main hardware components include:

i. NodeMCU ESP8266 (Node Micro Controller Unit): An open-source software and hardware development environment based on the ESP8266 chip. It integrates microcontroller capabilities and Wi-Fi access point functionality on a single board [13,14].

ii. DS18B20 sensor: It is a temperature-measuring sensor with high accuracy and ease of integration to the NodeMCU. The temperature measurement ranges of this sensor spans from -55°C to +125°C, with an accuracy of ±0.5°C within the range of -10°C to +85°C [15].

iii. MAX30102 sensor: Monitors heart rate and SpO_2 levels. Utilizing infrared and red light LEDs. Infrared LED is sufficient to measure the pulse rate, and both LEDs are required to determine SpO_2 level. The sensor operates effectively within a voltage range of 1.8V to 3.3V [16].

iv. DHT11 sensor: Measures temperature and humidity in the environment. It can measure temperatures from 0°C to +50°C with an accuracy of ±1°C and relative humidity levels from 20% to 90% RH with an accuracy of ±1% [17].

3.2. Software

The NodeMCU ESP8266 offers the advantage of being programmable in various programming languages and with an open-source Integrated Development Environment (IDE). Programming of NodeMCU ESP8266 is done in C++ for its robustness and ease of implementation. Data visualization and remote access are facilitated through the Cayenne IoT Cloud Platform, offering real-time monitoring of patient vital signs.

3.3. System Design

The proposed system consists of three tiers: (i) Sensing and Data Processing Tier, (ii) Data Storage Tier, and (iii) Output Tier. The sensing and data processing tier refers to the device held by the patient, while the data storage tier represents the cloud server, and the output tier includes the mobile/computer application and LCD display. Figure 4 illustrates the complete workflow of these three tiers. The sensing and data processing tier involves sensors that gather data from the patient's body and the room environment. This data is transmitted to the NodeMCU ESP8266 as electrical signals for processing and conversion from analogue to digital format. The NodeMCU

ESP8266 functions as a server (Wi-Fi module), transmitting the processed data to the cloud server via internet connectivity. The Cayenne IoT Cloud Platform stores and visually displays this data. Doctors or caretakers can access the Cayenne Platform through a computer or mobile application to view the data. Additionally, the LCD display can show measured data from the human body and the ambient environment. All information and communication between doctor and patient occur via the internet by creating an account on the Cayenne Platform ((my Devices Cayenne Platform)). Users must sign in with an ID to view vital data.

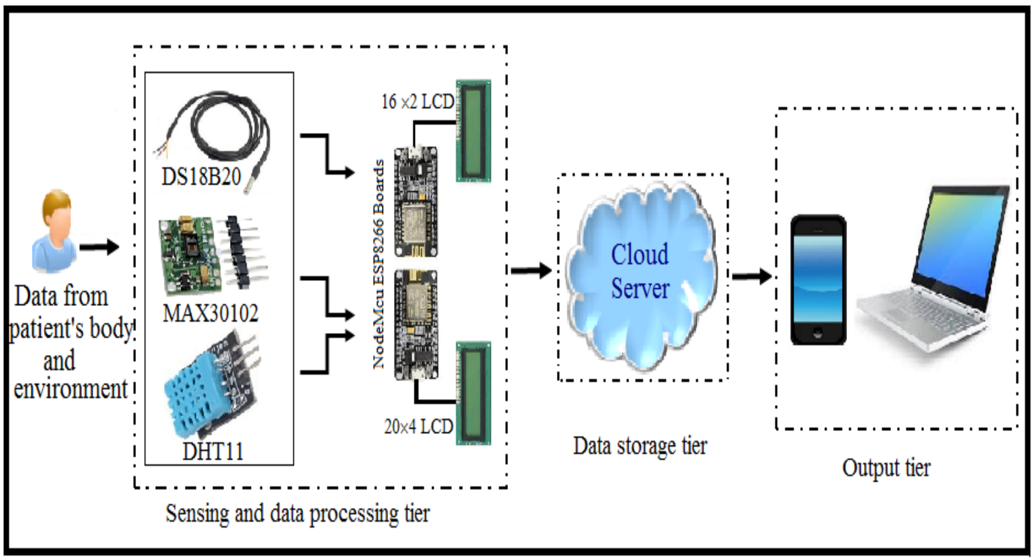

Fig 4. Workflow of the designed system

4. Study Site and Sample Size

Six male patients of different ages were randomly selected from Al-Zawia Hospital to participate in the study, which involved measuring pulse rate, SpO_2, body temperature, and environmental conditions in the room. Data collection was carried out over two days, January 3 and 4, 2023.

5. Study Reliability and Validity

After building the prototype circuit, it was initially tested to ensure proper functionality, data reliability, and accuracy. Subsequently, a series of tests were conducted using the proposed system on the patients to assess their pulse rate, SpO_2, body temperature, and room environment. Figure 5 illustrates some of the tests performed on patients to measure their vital signs, room temperature, and humidity.

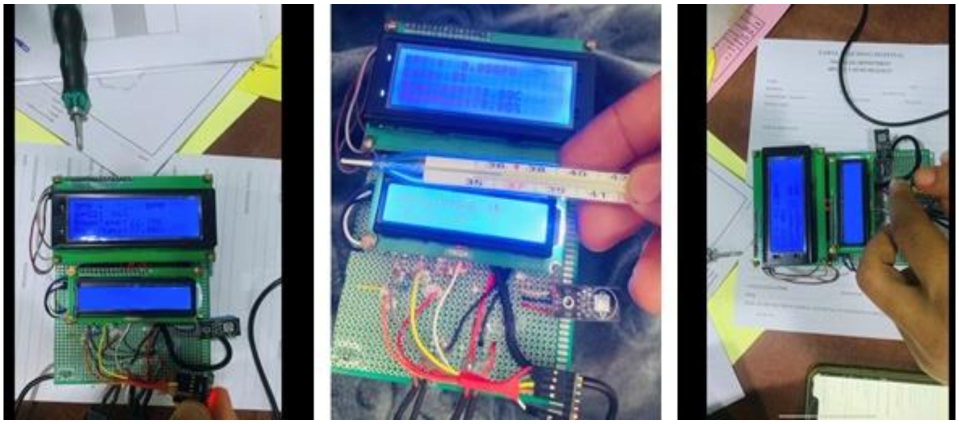

Figure 5. Testing the system on the patients

6. Experimental Results Analysis

To verify the performance of the proposed device, we compared its output with that of conventional hospital apparatuses. Data from the proposed device were displayed on a laptop application and an LCD. Experimental values from the designed device and the actual values from the conventional apparatuses were manually recorded. We calculated the percentage error and accuracy using equations 1 and 2 [18] to evaluate the effectiveness and performance of the designed system. Graphs were created using Microsoft Office Excel 2016.

$$Per\ cent\ error = \left| \frac{experimental\ value - actual\ value}{actual\ value} \right| \times 100 \ \ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

$$Accuracy = \left|1 - error\right| \times 100 \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

6.1. RESULTS

Tables 1, 2, and 3 present the proposed system data and actual results, including error rates and accuracy for pulse rate, SpO_2, and body temperature, respectively. Since there was no alternative device available for measuring room temperature and humidity, these parameters were solely measured using the proposed device, and the data are listed in Table 4. Figures 5a, 5b, and 5c show some of the data collected on the web server (Cayenne Platform) for pulse rate, SpO_2, body temperature, and room temperature/humidity. Figures 6a, 6b, and 6c illustrate the deviation of data obtained by the proposed system from actual data for pulse rate, SpO_2, and body temperature, respectively.

Table 1. Pulse rate test results

Patient No	Experimental value (bpm)	Actual value (bpm)	Error (%)	Accuracy (%)
P_1	91	90.38	0.68	99.3
P_2	92	93	1.07	98.9
P_3	88	88.09	0.1	99.9
P_4	80	80.64	0.79	99.2
P_5	83	81.87	1.38	98.6
P_6	76	78.85	3.6	96.4
Average	85	85.4	0.4	99.6

Table 2. SpO_2 test results

Patient No	Experimental value (%)	Actual value (%)	Error (%)	Accuracy (%)
P_1	94	94	0.0	100
P_2	96	99	3.125	96.8
P_3	95	97	2.06	97.9
P_4	97	99	2.02	97.9
P_5	96	99	3.125	96.8
P_6	96	99	3.125	96.8
Average	95.6	97.8	2.2	97.8

Table 3. Body temperature test results

Patient No	Experimental value (°C)	Actual value (°C)	Error (%)	Accuracy (%)
P_1	36.4	36.1	0.8	99.2
P_2	37.06	36.6	1.2	98.8
P_3	36.6	36.3	0.8	99.2
P_4	36.8	36.4	1	99
P_5	36.38	36.1	0.7	99.3
P_6	36.4	36.5	0.2	99.8
Average	36.5	36.35	0.4	99.6

Table 4. Room temperature and humidity test results

Readings No	Room temperature (°C)	Room humidity (%)
1	21	40
2	22.6	37
3	22.7	37
4	22.9	34
5	22.9	34
6	20	42
Average	22.01	37.3

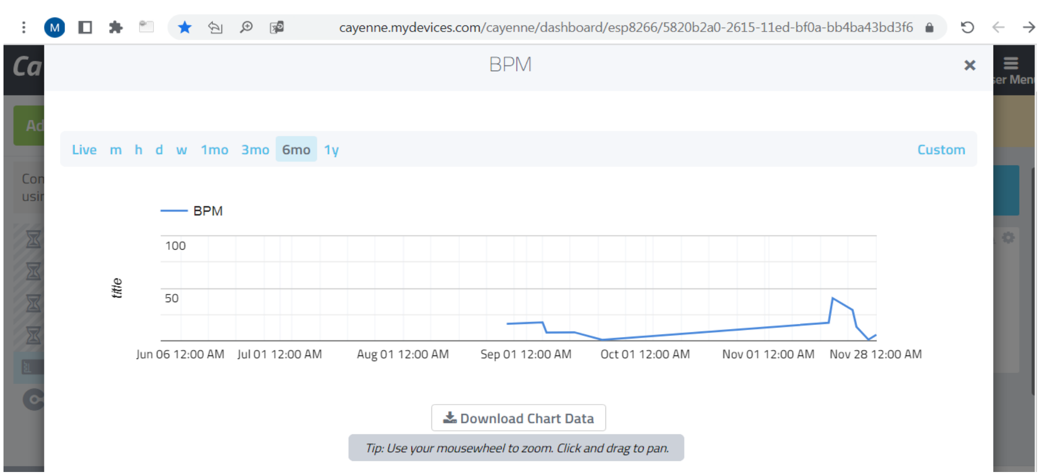

Figure 5a. Pulse rate/ SpO_2 result collected on the web server

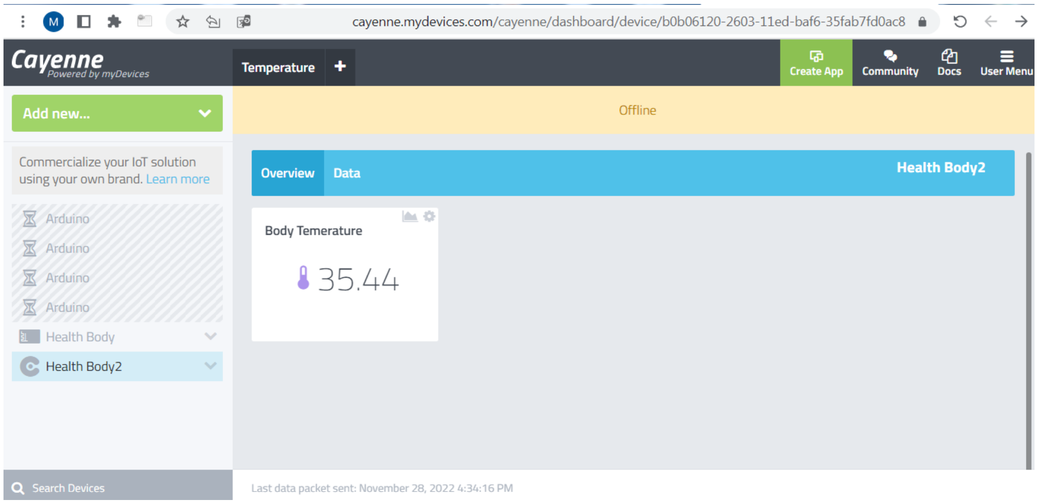

Figure 5b. Body temperature result collected on the web server

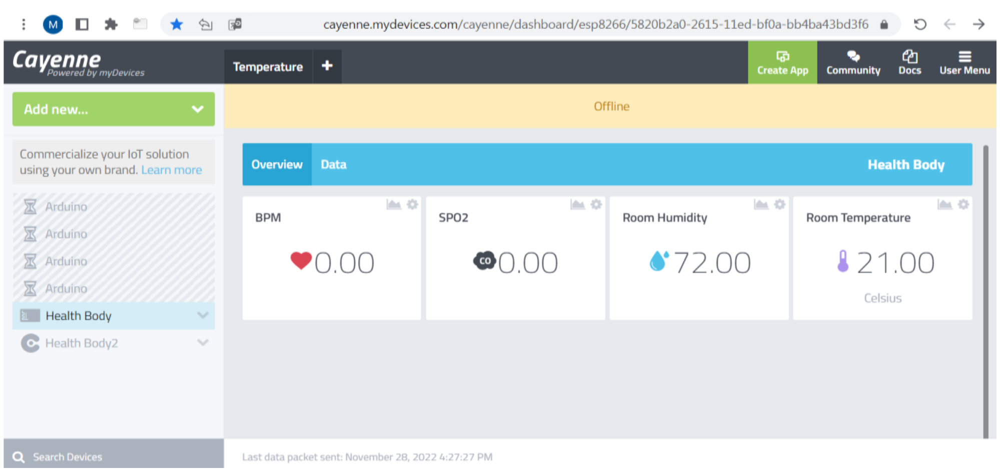

Figure 5c. Room temperature/humidity result collected on the web server

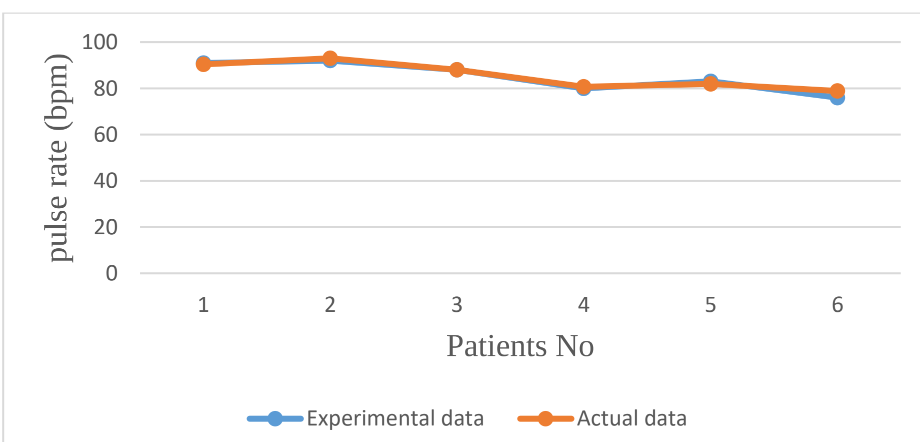

Fig 6a. Test result of the experimental and actual data of pulse rate

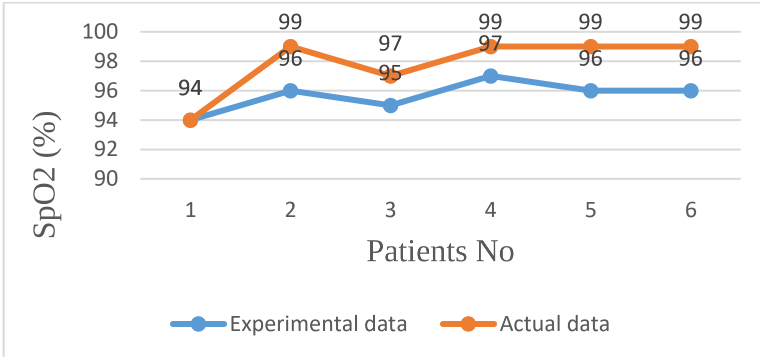

Fig 6b. Test result of the experimental and actual data of SpO_2

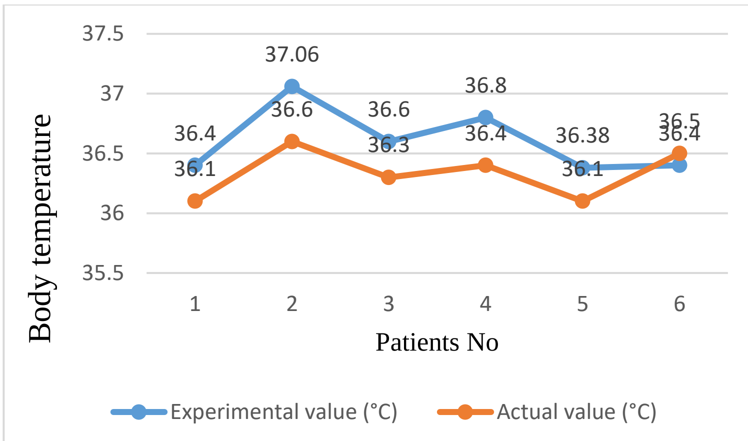

Fig 6c. Test result of the experimental and actual data of body temperature

7. Discussion

By comparing the results, it is evident that there are slight variations between the experimental data and the actual data. The pulse rate data from the proposed system ranged from 92 to 76 bpm. The highest error rate observed was 3.6%, with the lowest error at 0.1%, resulting in an average error rate of 0.4%, and an average accuracy of approximately 99.6%. These variations may be attributed to patient movement during examination, leading to sensor displacement on the fingertip. The pulse rate was measured by lightly touching the sensor with the index finger, where light passes through the fingertip. Additionally, light scattering from other sources also contributes to the observed differences. In SpO_2 measurement, readings for the six patients ranged from 94% to 97% with an average error of 2.2% and an average accuracy of approximately 97.8%. Variation may arise from patient's finger movement, as the same sensor was used for both pulse rate and SpO_2 measurements. The sensor utilizes two LEDs (Red and Infrared) for SpO_2 measurement: oxygenated haemoglobin absorbs Infrared light and reflects back the Red light, while deoxygenated haemoglobin absorbs Red light and reflects back the Infrared light. The sensor analyses these different absorption levels to determine SpO_2 levels. For body temperatures, six cases were evaluated using a sensor placed under the armpit. Recorded temperatures ranged from 36.38°C to 37.06°C, compared to thermometer results ranging from 36.1°C and 36.6°C. Temperature measurements taken with the proposed device closely matched actual thermometer values, with an average error rate of less than 0.5% and an accuracy of approximately 99% which is considered acceptable. This high accuracy can be attributed to the sensor's precision in measuring body temperature. Regarding humidity and room temperature measurements, the first five readings were taken in the hospital room, while the sixth reading was in the office of the Medical Engineering Department at the College of Medical Technology. Although differences in room temperature and humidity measurements were slight, they could be attributed to daily weather changes.

8. Conclusion

The current study presents the design and implementation of a healthcare monitoring system using IoT. The proposed system is able to collect patient's vital signs using various sensors and transmit the data to an application via the website. The data is also displayed on an LCD screen, allowing patients to monitor their health status promptly. Doctors can access the data through the website. Comparison of the system's readings with those of conventional devices shows no significant difference in findings, with a success rate exceeding 95%, and an average measurement error of 0.5%.

9. Challenges and Future Work

Throughout the development process, we encountered several significant challenges. Initially, we utilized a single NodeMCU ESP8266 board to connect all sensors and a 20×4 LCD screen. However, this configuration resulted in the LCD screen not displaying all the data and the body temperature sensor failing to operate properly. To overcome these issues, we implemented a solution using two NodeMCU ESP8266 microcontrollers: one dedicated to the temperature sensor and a 16×2 LCD screen, while the other managed the remaining sensors and a 20×4 LCD screen.

In the future, the system could benefit from enhancements and modifications by utilizing a single NodeMCU ESP8266 microcontroller instead of two, which would necessitate a high-quality screen capable of displaying all sensor data received. Additionally, we plan to integrate new sensors, including a blood pressure sensor, an electrocardiogram sensor, and a diabetes level sensor. These additions will enable the system to monitor comprehensive vital signs, crucial for assessing a patient's condition effectively.

Acknowledgments

We sincerely thank the patients for their participation and cooperation, which made this study possible.

References

[1] Anooz, R. (Aug. 2018). *Remote Patients Monitoring System (Heartbeat and Temperature) using Arduino*, International Journal of Scientific & Engineering Research, Vol 9, Issue 7, pp 1859-1 863 Issn 2229-5518.

[2] Alumona, T. L., et al, (Sep. 2014). *Remote Monitoring of Patients Health using Wireless Sensor Networks (WSNs)*, IIJEC, Vol 2, Issue 9.

[3] Tasniem, A., et al, (2016) *Development of Application-based Health Monitoring System using GSM module*, Bachelor Degree of Science in Computer Science and Engineering. BRAC University.

[4] Polu, S. (Mar. 2022) *Design of Remote Patient Monitoring System for Chronic Diseases*, IJARCCE, Vol 11, Issue3. doi:10.17148/IJARCCE.2022.11308

[5] Polu, S. K. (Aug 2022). *Design of an IoT-based Heart Rate Monitoring System for Cardiovascular Patients*, IJARCCE 11(8):11-13.

[6] Bhuiyan, M. N., et al, (2022). *Design and Implementation of a Feasible Model for the IoT Based Ubiquitous Healthcare Monitoring System for Rural and Urban Areas*. Digital. Object Identifier 10.1109/ACCESS.2022.3202551.

[7] Chandana, M., and Arun, M. R., (Oct 2020). *An IoT based Patient Health Monitoring System using Node MCU*, RJET, Volume: 07 Issue: 10.

[8] Gregoski, M., et al. (Jan. 2012*). Development and validation of a smartphone heart rate acquisition application for health promotion and wellness telehealth applications.* International Journal of Telemedicine and Applications. Vol 2012, Article ID 696324, 7 pages .https://doi.org/10.1155/2012/696324.

[9] F. M. Yassin, N. A. Sani, and S. N. Chin, (Nov. 2019). *Analysis of heart rate and body temperature from the wireless monitoring system using Arduino*, Journal of Physics: Conference Series, vol. 1358, pp. 1–6, Article ID 012041.

[10] Islam, M. M., Rahman, A., and Islam. M. R., (2020). *Development of the smart healthcare monitoring system in IoT environment*, SN Computer Science, vol. 1, no. 185.

[11] Abed, N. J., & Hussein, E. A., *Design and Implementation of Real-Time Health Care Monitoring System Based on IoT*, J. Phys. Conf. Ser 1818 (2021) 012044.

[12] Khan, M., et al, (2022). *IoT-Based Health Monitoring System Development and Analysis, Security and Communication Networks*, Volume 2022, Article ID 9639195, 11 pages, https://doi.org/10.1155/2022/9639195.

[13] Dhairya Parikh, (2022). Raspberry Pi and MQTT Essentials “Electronic version”. Birmingham. Packet Publishing Ltd.

[14] *"NodeMCU - A Perfect Board for IoT"*. *circuito.io blog. 2018-11-21. Retrieved* 2021-05-27.

[15] Hazwani, A., et al, (2017). *Design and Development of Patient Monitoring System.* IOP Conf. Ser: Mater. Sci. Eng. 226 (2017) 012094. doi:10.1088/1757-899X/226/1/012094

[16] https://www.amazon.in/xcluma-MAX30102-Upgraded-Ultra-Low-Compatible/dp/B07TZCNG2G

[17] https://create.arduino.cc/projecthub/MisterBotBreak/how-to-use-temperature-and-humidity-dht-sensors-9e5975

[18] Molokhia, I. M., & Saleh I. M., (2002). *Electrical measurements*, ELGA.