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Remote Healthcare: Development of a Centralized Patient Monitoring System for Ward Patients

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Abstract

Patient monitoring is an essential practice in healthcare settings to assess well-being and medical conditions. This study proposes a central patient monitoring system enabling healthcare personnel to have a comprehensive perspective of multiple patients' health state from a central location. The proposed prototype enables healthcare providers to detect and respond to changes in patients' condition efficiently. The project contains multiple patient monitoring units with each measuring temperature, ECG, SpO2, and heart rate along with a display on a centralized screen. The hardware of monitors is placed at each patient bed connected with all the patients and the result of each patient can be seen from the general ward counter. Different sensors are used to design monitoring units and are connected with node MCU through different pin connections. Node MCU sends the information gathered from sensors to the Raspberry pi unit using Wi-Fi. The real-time data of patients are being displayed and saved using server "thing speak". There are different options on the server window to switch between different patients' real time results to monitor them. The proposed prototype uses computer technology to monitor the vital signs of multiple patients on a single monitor from a centralized location using internet which may eventually reduce the time and workload of medical staff leading to improved patient care.

Keywords: Health data analytics, vital signs, remote Healthcare, Raspberry pi, Biomedical sensors.

INTRODUCTION

With the advancement in cutting-edge medical technology, healthcare sector is aggressively coming up with innovative facilities for better healthcare services. Centralized patient monitoring is a critical aspect of providing care to admitted patients in the hospital. The utilization of modern computing sciences in large-scale data, genomics, and artificial intelligence are merely a few examples of the growing fields that come together under the broad umbrella term of digital health, which also includes mHealth (Rayu et al., 2012) The mHealth is mobile computing, medical sensor, and communication technologies for health care (Istepanian et al., 2004) The saturation level of oxygen and blood pressure are measured using photo plethysmography technology.

A linear regression is employed to identify and categorize an arrhythmic heartbeat using a heart rate sensor (Abay et al., 2018) In accordance with NICE clinical guidelines, at the very least, the following kinds of physiological observations are to be noted during the preliminary evaluation and as part of regular monitoring of patients. Respiratory rate, heart rate, systolic blood pressure, level of consciousness, oxygen saturation, temperature (National Institute for Health and Care Excellence et al., 2003) Internet of things (IoT) is a term used to define connections to all computing, digital and mechanical technologies to transfer the data through the Internet without human interferences. The major objective of this technology is to be sure that Internet-based communications and the sending and receiving of information are generally available when used with electronic sensor devices (Nazir et al., 2019) In order to support Internet of Things applications, cloud infrastructure consists of a number of servers that are connected to one another and carry out machine learning and artificial network applications (Ren et al., 2018) Approximately 28.4 billion users of this Computing technology in 2017 and they have gone up to 50.1 billion by 2020, the WSN is an important part of IoT and is important for its applications in healthcare. WSN have become known for their advanced and varied wireless control methods. Rotariu and Manta put attention on creating the WSN for pulse rates and oxygen saturation in 2012.

On the other hand, Yue Hong worked to have blood pressure and ECG sensors on mobile phones in 2016 (Nazir et al., 2019; Yasin et al., 2017). A new generation of communication technology known as LPWANs (low power wireless area network) is designed to provide long-distance communication at low cost, high transmission range, low energy consumption, and a longer battery life (Mekki et al., 2018). Healthcare is developing LPWAN-based IoT applications. The idea of connecting anybody, anything, anyplace, and any network is put into practice with these devices. This facilitates the realization of automation in healthcare sectors (FouedMelakessoun et al., 2020) Due to advancements in the fields of artificial intelligence, machine learning, and communication technologies, it is very likely that these networks will be utilized to further innovate already-existing applications (K. Padmanaban et al., 2022). Smart grid, transportation, and healthcare are three industries that are developing LPWAN-based IoT applications. These LPWAN networks allow the linked devices to communicate the physical parameters that are sensed to the centralized gateway, which can use machine learning algorithms to make the essential decisions. Applications are limited by low complexity and energy efficiency for a salable network, where nodes come and go regularly.

One such LPWAN protocol is LoRa (low power long range), which is designed for use in healthcare systems to transmit data from sensors (Chaudhari et al., 2020) The LoRa transceiver can be used to send all patient health data to the cloud, the transceiver is useful for connecting devices in healthcare it works by transmitting and receiving radio frequency signals in a unique method that can travel great distance to communicate (Augustin et al., 2016) In such instances, end devices have limited energy (for instance, battery-powered) and can only send a small number of bytes at a time (Hassanalieragh et al., 2015) Additionally, data traffic can be initiated by the end device itself or by an outside party that wants to communicate with the end device (Lali Ismail et al., 2018; Ismail et al., 2018) Block chain is also useful technology integrated with IOT in data transmission, according to Deloitte's 2019 Global block chain Study. The objective of block chain in healthcare is to establish a transparent, safe, and reliable system for managing patient data. This system will guarantee that information is private, correct, and easily available to those with authorization, which will ultimately improve patient outcomes and care (Azbeg et al., 2021) Generally, nursing staff is responsible to regularly visit each patient bed and check vital signs of the patients admitted in the ICU, HDU, CCU and general wards. Some critical patients need serious and efficient care in monitoring their vital signs as delayed monitoring can lead to dangerous deteriorations (WHO et al., 2019). The Proposed Project Centralized Patient Monitoring System is a set of processes that enables healthcare providers to monitor the health of multiple patients on a single screen without going to each patient's bed. The project involves monitoring of different physiological parameters that include heart rate, body temperature, oxygen saturation of blood and ECG in real time.

MATERIALS AND METHODOLOGY

In order to initiate the development process of Centralized Patient Monitoring System, a set of fundamental stages act as a roadmap for the methodological development. The following steps include the sensor integration, ESP8266 programming, Raspberry Pi connection, and Thing Speak server setup in an easy way.

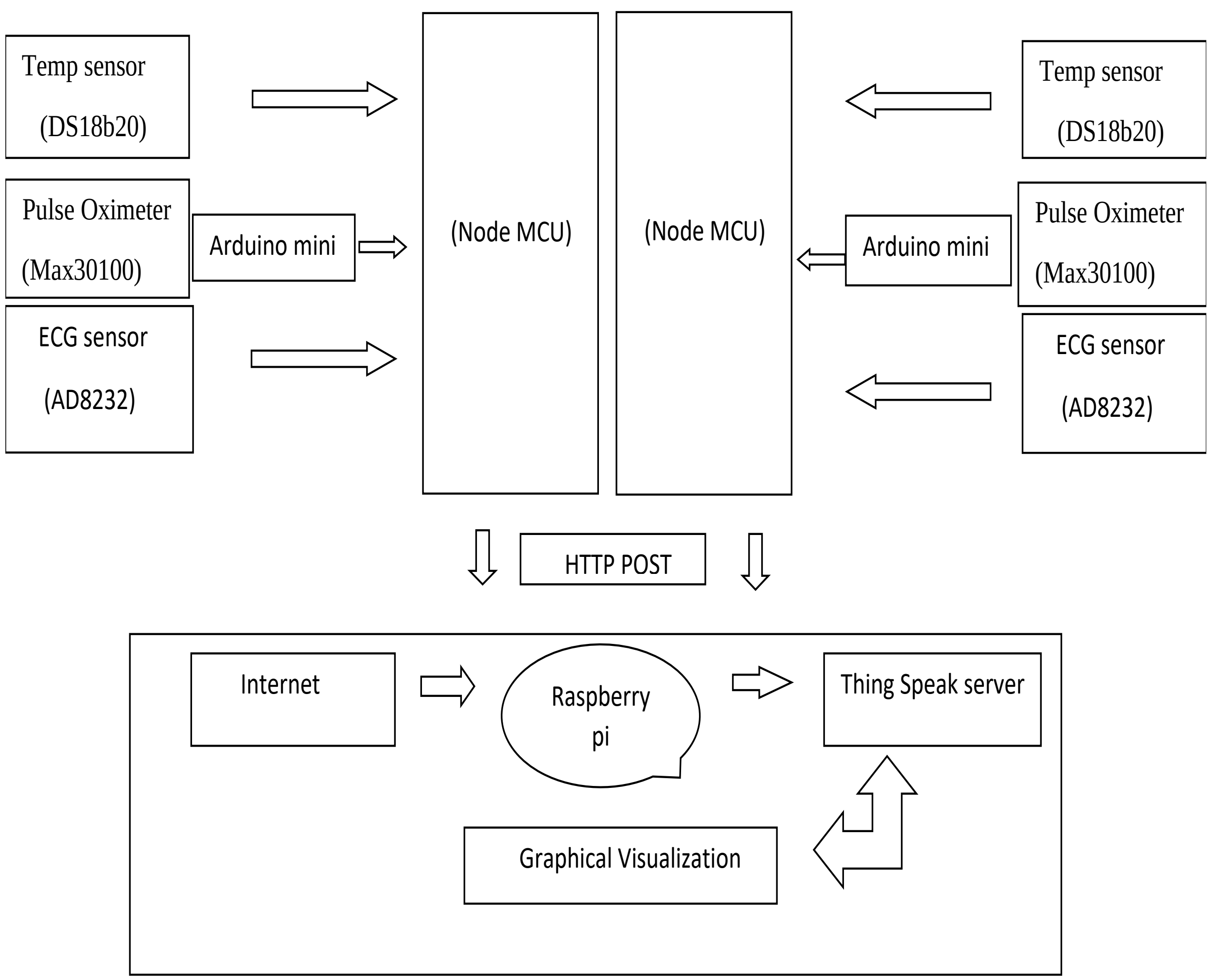

Figure 1.
Block diagram of Centralized Patient Monitoring System

- ### Sensor's integration:

As shown in fig 1, The AD8232 sensor and ESP8266 are linked for the purpose of recording an ECG. AD8232 is a sensor used to measure electrical activity of heart. This is made possible by careful wiring and code that is implemented in the Arduino IDE. At the same time, the monitoring system contains MAX30100 sensor, which measures pulse rate and heart rate. MAX30100 contains an advanced integrated pulse oximeter and heart rate sensor IC from analogue device. It detects heart rate (HR) and oxygen saturation (SpO2) signals by using photodetectors and LEDs. It systematically runs the Arduino code that's linked to the ESP8266 connection. Furthermore, the temperature-measuring DS18B20 sensor is presented. DS18B20 is a 1-wire programmable temperature sensor made by Maxim Integrated (DS18B20 et al., 2019). The sensor is a fantastic alternative for many temperature measurements without taking up many of the microcontroller's digital pins because it only requires one signal pin of the MCU to transport data and has a unique address. It seamlessly integrates with the ESP8266 and implements the necessary code to retrieve data.

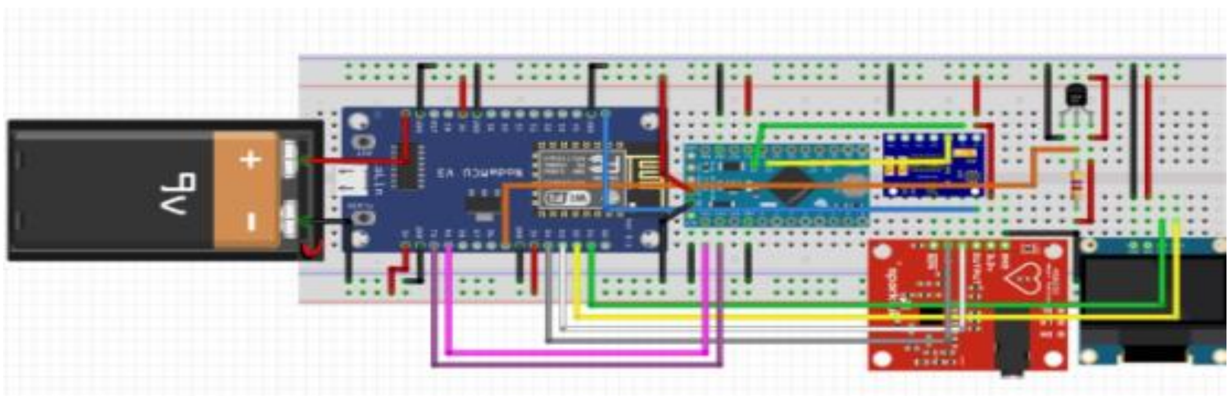

Figure 2.
Pin configuration circuit diagram

The Arduino IDE enables programmable configuration that allows the ESP8266 to be easily linked with a variety of sensors. Important libraries are installed during the setup process to ensure successful operation of the AD8232, MAX30100, and DS18B20 sensors. The ESP8266 is an essential element for many different Internet of Things applications because of its potent Wi-Fi module and simple development board. The ESP8266 can connect to the internet and other devices by utilizing its built-in Wi-Fi capabilities. This allows for remote control and makes sharing information with sensors easier (ESP8266 NodeMCU et al., 2023). The ESP8266 is configured to create a secure wireless connection after this integration. The carefully designed data transmission protocols such as SSID and password authentication, are essential to this procedure. This all-inclusive configuration ensures the ESP8266's effective involvement in Internet of Things applications by integrating sensor capabilities with strong connection.

- ### Raspberry pi integration:

Raspberry Pi is a small-sized computer that runs on Linux-based operating systems. It has a wide range of applications in home automation, education, remote control system. In the centralized patient monitoring system project, Raspberry Pi is used as a gateway to receive and process data from sensors, such as the AD8232 ECG sensor, connected to the ESP8266 (Ganesh et al., 2019). Install OIS on the Raspberry Pi for correct operation. Careful testing is a part of the setup procedure to identify and fix any possible connectivity problems. Next, a Raspberry Pi server called Thing Speak is set up to collect, store, and display data from the integrated sensors. Thing speak generates specific API Key for specific channel. this API Key is programmed in ESP8266 for security purpose. A smooth connection is made between the ESP8266 and Thing Speak, guaranteeing data transmission. In addition, a mobile application which is known as Thing Show also used to retrieve data from sensor by using API key.

- **Real time Data Visualization:**

The Thing Speak integration is expanded to include setting up of channels for the purpose of organizing and obtaining sensor data streams. The configuration that follows creates dynamic graphs and visualizations that show temperature, heart rate, oxygen saturation and ECG data in real time. Thing Speak has procedures in place for continuous monitoring to ensure that health parameters are updated on time to prevent from misdiagnosis.

RESULTS & DISCUSSIONS

The Centralized Patient Monitoring System successfully collects real-time data from a pair of volunteers. A total of 50 volunteers participates as sample for the study, their vital signs, including heart rate, body temperature, ECG, and SpO2, are continuously monitored using two dedicated monitors. The collected data is centralized, allowing healthcare providers to access it from a single platform. The analysis of the centralized monitoring system's performance reveals an impressive overall accuracy rate of 95%. The efficiency of the system not only ensures the timely detection of anomalies but also reduces the burden on healthcare professionals. Below is the experimental setup of project in fig 3.

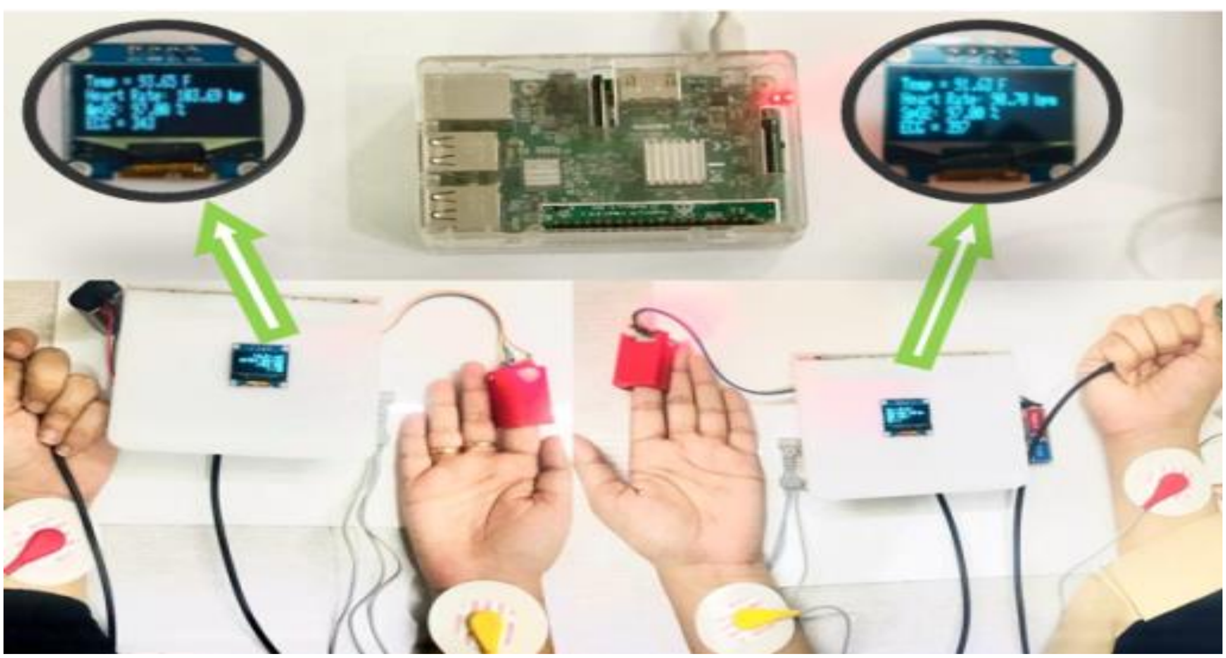

Figure 3.
Experimental setup of two patient monitors o two volunteers

In order to do the procedure, two patients are linked to two of the patient monitors, and their readings are taken using sensors that are connected to the patients, such as temperature sensor, ECG sensor, SpO_2 sensor, and heart rate sensor. Shown in fig 3 experimental setup the two patient monitors are constructed utilizing various sensors, parts, computer programming and tools. The measurements are transferred to Arduino, which delivers the patient data to the ESP8266. The ESP8266 Node MCU, which has built-in Wi-Fi, is wirelessly connected to raspberry pi, which centralizes the data it receives from the node. While the Thing speak Platform is an online server that enables the simultaneous, real-time display of both patients' data on a single LCD. Thing speak displays two channels BED1 and BED2 in Fig 4 With one click the channels can be inter switched with BED1 patient to BED2 patient and vice versa.

Figure 4.
each two channels have 4 fields for 4 parameters

Two channels are created on thing speak shown in Fig 4, each channel has individually four fields for each patient, each of the field displaying a different parametric graph for patients and data can be stored for later use. The results of both patients are displayed in Fig.4 which is a graphical depiction of four parameters: ECG, temperature, heart rate, and SpO2. Thing speak can display the graphically, numerically, or tabulated.

Table No:1
The Repeatedly Results Of Patient 1 At Different Times

TIME	TEMPERATURE	SPO2 (%)	HEARTBEAT (HR)	ECG
9AM	97.12	97	78.12	673
11AM	98.22	95	78.28	669
1PM	98.75	97	80.08	668
3PM	97.35	96	72.01	670
5PM	97.12	96	75.3	669
7PM	96.34	98	76.5	670
9PM	98.05	97	77.23	665
11PM	99.24	95	80.2	668
1AM	98.13	96	79.5	678
3AM	95.28	95	77.6	689
5AM	97.56	95	78.23	692
7AM	95.34	97	73.56	692
9AM	98.12	98	80.12	690
11AM	97.23	96	81.34	679
1PM	97.12	95	79.12	688
3PM	98.23	98	80.23	679
5PM	99.11	96	80.12	689
7PM	98.45	97	78.45	692
9PM	97.34	98	81.45	695
11PM	98.21	96	79.54	690

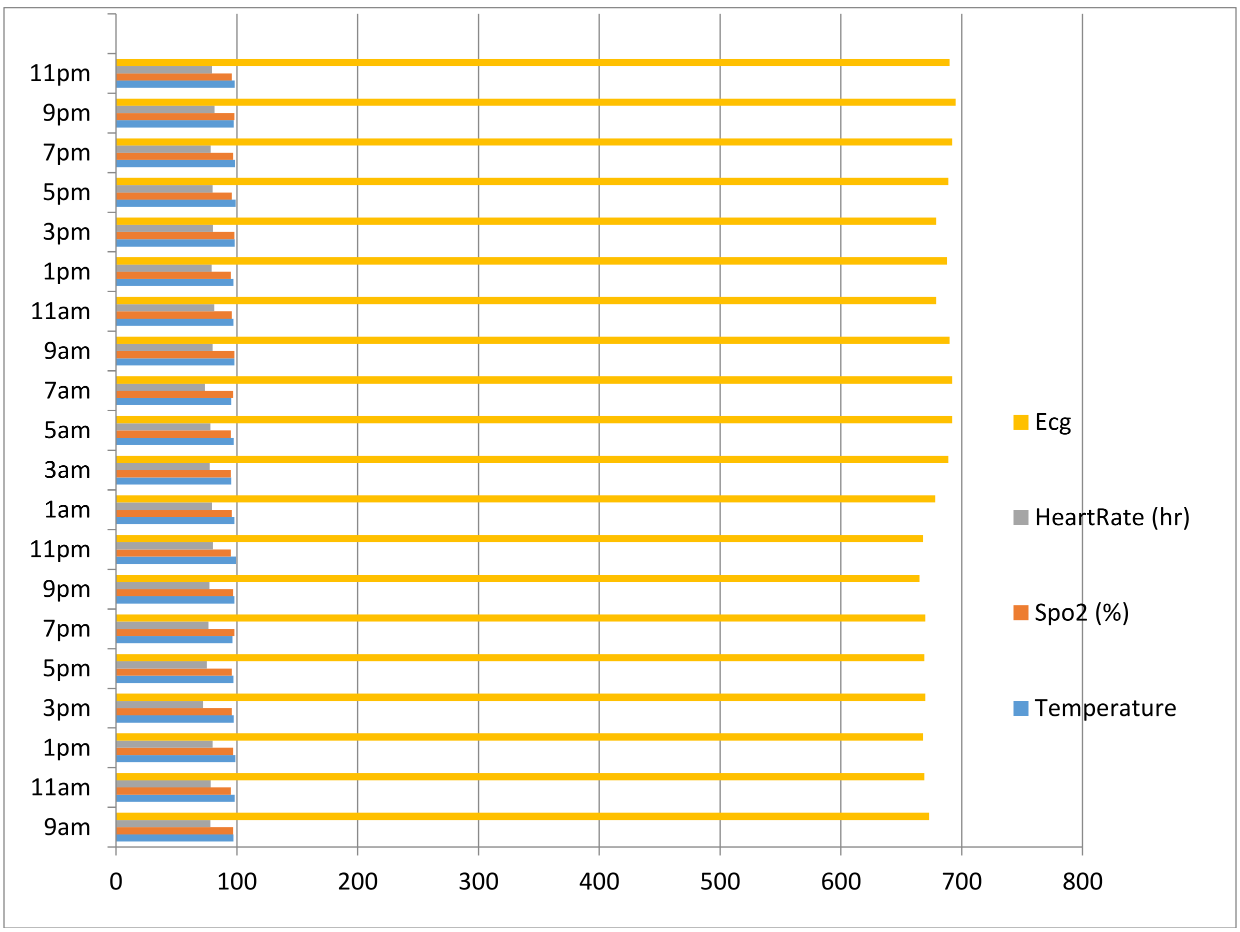

Figure 5.
1st volunteer repeatability results

Table2.
Shows the Repeatedly Results Of Patient 2 At Different Times

TIME	TEMPERATURE	SPO2 (%)	HEARTBEAT (HR)	ECG
9AM	98.22	98	77.13	660
11AM	99.12	97	76.29	648
1PM	97.75	99	81.82	655
3PM	96.85	98	73.03	668
5PM	97.12	98	76.32	659
7PM	98.14	97	77.15	664
9PM	99.04	96	77.23	659
11PM	98.16	95	81.32	663
1AM	97.85	96	80.15	660
3AM	98.35	98	79.26	668
5AM	99.12	99	82.23	665
7AM	97.94	96	80.26	658
9AM	98.12	97	79.17	649
11AM	98.23	98	78.54	655
1PM	99.16	97	77.67	669
3PM	97.34	95	80.12	670
5PM	98.1	96	78.16	668
7PM	97.54	97	79.55	659
9PM	98.21	98	81.65	648
11PM	98.28	99	80.54	655

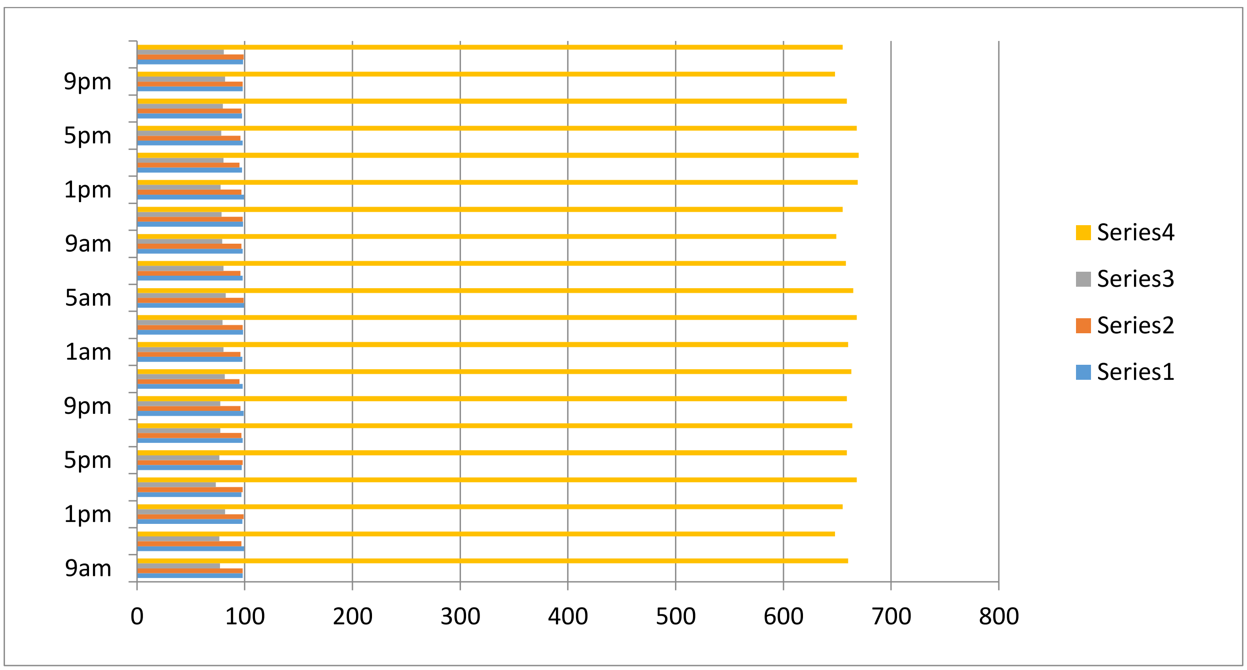

Figure 6.
2nd volunteer repeatability results

Fig 5 and 6 show the visual representation of data results in the form of a chart that is taken at different time intervals of 2 hours in 2 days. In which 20 samples of each patient (volunteer) are taken at different times to check the differences in the result and compare the accuracy of both monitors for four parameters (TEMPERATURE, ECG, SPO2, AND ECG) are used to detect the samples. both monitors measured the physiological parameters at 20 different timings. It measures readings at 5am, 7am, 9am and in the afternoon the reading is taken at 3pm, 5pm, and at the night readings was taken at 7pm, 9pm, 11pm, and 1am and other reading was taken at the mid night at 3am, 5am and remaining reading was taken next day in the morning 7am, 9am, 11am, and 1pm after that at 3pm, 5pm, 7pm, 9pm and last at 11pm. We have used bar chart to represent our data and repeatability that showed the accuracy of 98% and mean variation is 1.05%

CONCLUSION

The Centralized Patient Monitoring System presented in this project harnesses the power of Raspberry Pi and various sensors to provide an effective, efficient, and centralized approach to monitor the patients admitted in hospital wards. This work has successfully demonstrated the capabilities of a patient monitoring system that can measure and transmit crucial health parameters, including body temperature, SpO2 levels, heart rate, and ECG data. The Raspberry Pi acts as a central hub, collecting data from multiple sensors and wirelessly transmitting it to the Thing Speak cloud platform, where it can be monitored and analyzed remotely in real-time. One of the significant advantages of this system is it allows healthcare providers to continuously monitor patients' vital signs, enabling early detection of abnormalities and immediate action. Furthermore, the project highlights the versatility and scalability of the system. It can be customized to monitor various vital signs beyond those presented here, making it adaptable to different patient care scenarios. Moreover, the use of open-source hardware and software components, such as Raspberry Pi and Thing Speak, makes the system cost-effective and accessible to a broader range of healthcare facilities.

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Authors' contributions: Each author participated equally to the creation of this work.

Conflicts of Interests: The authors declare no conflict of interest.

Consent to Participate: Yes

Consent for publication and Ethical approval: Because this study does not include human or animal data, ethical approval is not required for publication. All authors have given their consent.

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