

Research Article

IoT-Based Healthcare Monitoring Using Raspberry Pi Performance Analysis of Multiple Medical Sensors



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ABSTRACT

This paper presents the design and a preliminary experimental study of an Internet of Things (IoT) healthcare monitoring prototype based on Raspberry Pi and a collection of medical sensors that provide real-time patient monitoring. The system includes sensors to measure heart rate, blood pressure, blood glucose, temperature, and blood oxygen saturation, as well as a GPS sensor that provides the patient's location. Data from these sensors is sent to a cloud-connected desktop application, allowing remote physicians to monitor the patient remotely. The experimental evaluation was carried out on a small case study involving two patients, and some measurements were compared with those obtained using traditional devices and GPS devices. Heart rate sensors produced values of 78 and 81 bpm, compared with 77 and 78 bpm from a traditional device. Blood pressure sensor results were 116/77 and 120/79 mmHg, while traditional devices gave results of 117/78 and 122/80 mmHg. GPS sensor results closely matched standard GPS coordinates from a mobile phone. These results demonstrate the proposed prototype's ability to collect and transmit multiple body measurements to a unified, low-cost platform. However, the small scope of this initial case study does not establish clinical equivalence or appropriateness as a replacement for traditional devices. The main contribution of this work is combining multiple sensing functions, remote data transmission, and physician-oriented diagnostic monitoring within a single Raspberry Pi platform. Future work should include broader clinical evaluations over longer periods, as well as security and privacy considerations and the integration of artificial intelligence techniques.

1. INTRODUCTION

Recent decades have seen considerable progress in IoT technology, significantly boosting the healthcare industry by enabling remote patient monitoring, real-time acquisition of vital parameters, and telemedicine, resulting in early clinical diagnosis and rapid patient interventions [1]-[3]. In addition to improving the overall quality of medical services, IoT reduces hospital visits and, consequently, enhances patient satisfaction [3], [4].

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This research designs and implements a smart health monitoring system integrated into a Raspberry Pi with multiple medical sensors. This health monitoring system measures important parameters such as blood oxygen level (SpO₂), body temperature, heart rate (HR), etc. It transmits them over IoT-based networks, helping healthcare workers quickly access the patient's medical information and take necessary action when abnormalities are detected [3], [5]. Many such systems have been built on Raspberry Pi because of its low power, low cost, versatility, and the availability of several sensors and communication modules [5], [6]. The Internet of Things provides a universal network where humans can interact with everything ranging from smartphones, wearables, sensors, physical assets, devices, to virtually everything on Earth through the Internet for accessing or sharing information, which leads to a wide spectrum of IoT-based applications, including the use in human healthcare [1], [2]. The Internet of Things (IoT) is the concept of connecting everything to anything via the Internet without human intervention.

The Internet of Things consists of billions of devices with unique identifiers that can send data to each other over the Internet with minimal human interaction [1], [2]. The continued growth of high-speed wireless networks, cloud computing, big data analytics, and Artificial Intelligence (AI) technologies accelerates the development of IoT applications across all fields; healthcare is one of the fastest-growing IoT market segments [2], [7]. Many factors drive IoT adoption in healthcare. For instance, an increasing elderly population, a growing prevalence of chronic diseases, limited access to medical care in remote areas, rising healthcare costs, and growing patient interest in remote healthcare services in developing regions.

These issues highlight the importance of researching the Internet of Things for intelligent healthcare [3], [4], [8]. Healthcare IoT, also called the Internet of Medical Things (IoMT), refers to the ecosystem of medical devices, applications, health systems, sensors, wearables, and underlying connectivity services that connect them to the Internet [4], [7], [8]. IoMT devices and applications can help predict diseases and health risks, provide a broad range of diagnostic information, improve in-patient or home care by monitoring patients, and support various clinical and non-clinical services [4], [7], [8].

Broadly, billions of IoT devices are now connected to the Internet worldwide. These IoT devices support various application scenarios such as health care, transportation, manufacturing, logistics, agriculture, smart cities, and the environment [9]. IoT is one of the most impactful twentieth-century technologies, enabling pervasive communication by connecting people and processes to devices through embedded connectivity [2], [9]. Despite its advantages, IoMT faces challenges in security and privacy, reliability, interoperability, and energy efficiency that need further study [7], [8], [10]. The remainder of this paper is structured as follows: Section 2 reviews relevant previous work on IoT-based healthcare monitoring systems.

This paper considers the challenges of conventional healthcare monitoring systems, such as high cost, remote-access constraints, and the inability to integrate various physiologic sensors into a single system. This paper proposes an IoT-based healthcare monitoring system using a Raspberry Pi to monitor and transmit a patient's vital data.

Section 3 presents a detailed description of the proposed methodology, system architecture, algorithm, communication protocols, and implementation. Section 4 illustrates the experimental setup and the results collected. Section 5 discusses the results and compares them to those of other studies. Lastly, Section 6 provides a conclusion and future work directions for this study

2. Related Work

Yuehong Yin and others examined how technologies such as information technology (IT) can supplement and improve existing healthcare services. The Internet of Things (IoT), in particular, has been widely used to connect existing medical resources and provide reliable, efficient, and intelligent healthcare services to the elderly and patients with chronic diseases. This study aimed to summarise IoT applications in healthcare and highlight current trends and future research directions. Based on a thorough literature review, this study examines advances in IoT in healthcare systems from the perspectives of supporting technologies and

methodologies, smart IoT-based devices and systems, and diverse IoT applications in healthcare. This promising research motivated further work on using the Internet of Things to address diseases and improve healthcare [11].

Aghdam, Z.N. et al. [12] examine recent breakthroughs in the Internet of Things (IoT) as it advances in the healthcare industry. They found that the Internet of Things will help doctors and hospital workers carry out their tasks more comfortably and intelligently. Recent sophisticated technologies have addressed most obstacles to using the Internet of Things; overall, this technology has the potential to drive a major revolution with several benefits in the digital future[13]. Healthcare is one of the most advantageous applications of IoT. IoT's most significant applications include monitoring and making timely judgments in critical situations. This technology-based approach offers an unprecedented opportunity to improve treatment quality and efficiency, improve patient health, and optimise government funding. This is what encouraged us to begin a practical project with real results.

In this study, Gupta MS et al. developed a system for continuous monitoring of Electrocardiogram (ECG) signals and other vital physiological parameters. The system stores the collected information in a database and makes it accessible through a secure web interface available only to authorised personnel. The proposed system uses a Raspberry Pi platform to provide an efficient, cost-effective monitoring solution. Its primary objective is to continuously update patient records and alert healthcare professionals when it detects abnormal readings.

To establish communication between the monitoring unit and the database, the researchers integrated Raspberry Pi and GSM modules using the MySQL database module. The monitored data represent a valuable resource for medical analysis and future scientific investigations. Furthermore, the system shows strong potential for supporting disease prediction by identifying patterns in the recorded physiological parameters. The outcomes of this research were used to develop an electronic model that monitors multiple vital signs, including ECG, blood glucose levels, and body temperature. This approach expands research opportunities in medicine and contributes to early disease prediction and diagnosis [14], [15].

3. Methodology

The application is built as an electronic system connected to the Raspberry Pi. It contains medical sensors connected to the patient's body, where the heart rate, blood pressure and blood sugar are measured by placing special sensors that measure the aforementioned health rates for each patient, as well as a GPS sensor to know the patient's position in the event of any occurrence of an abnormal condition and patient loss[16]. Furthermore, we use a communication protocol between controllers to collect data and transfer it from sensors to the doctor's monitoring system.

The system program app contains the code used by the Raspberry Pi console. The medical sensors used in the project are programmed using Python. In addition, Java is used to design the monitoring program, which is placed near the doctor via a desktop interface application [17].

We need a laptop with the application installed to monitor the patient's status; it is placed next to the supervising doctor, and sensors are applied to the patient. The patient database is associated with the sensors, collects results based on the disease condition, and stores them in the cloud; it then transfers them to the application next to the attending physician to display the results [8], as shown in Figure 1.

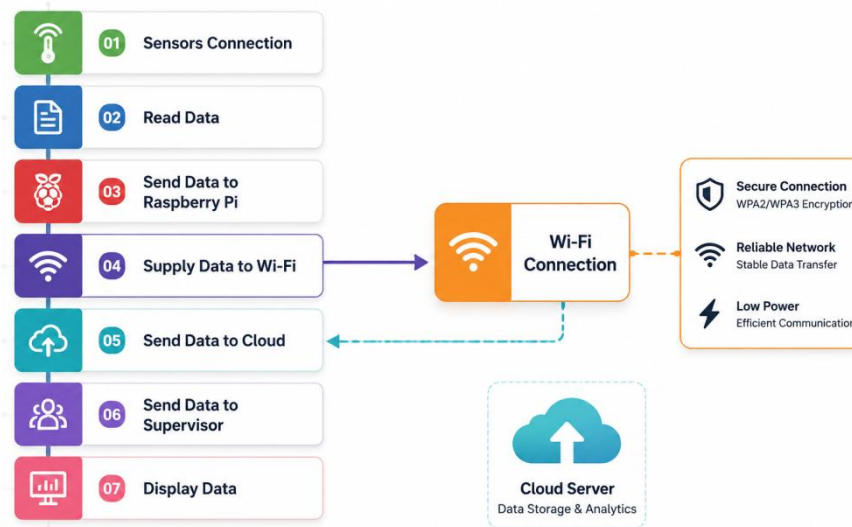


Figure 1. System Software Implementation

3.1 System Hardware and Technical Implementation

The proposed healthcare monitoring system integrates a Raspberry Pi as the communication and processing centre. Several medical sensors were connected to the Raspberry Pi, enabling it to measure physical and human body parameters, such as blood pressure, body temperature, heart rate, blood oxygen, blood glucose, and patient location using a GPS sensor. The Raspberry Pi collected these sensor measurements, then processed and transferred the data.

The patient's pulse rate was obtained using an optical pulse-rate sensor connected to the Raspberry Pi. The blood pressure was measured using a non-invasive blood pressure sensor, and blood glucose was collected via the established glucose-monitoring interface. For the patient's geographical location, the NEO-6M GPS module was used. Include the sensor specifications and electrical connections in a separate table: sensor type and model, operating voltage and interface, connection pins to the Raspberry Pi, and measured parameters.

The system architecture has four levels: sensors, Raspberry Pi, communication/cloud, and doctor observation. The sensors generate readings that describe the patient's condition and convert these data into digital signals for the Raspberry Pi to read, acting as an intermediary between the sensing device and the monitoring application. The system used USB-TTL serial communication between the blood-pressure measurement unit and the Raspberry Pi. The system sent patient information over the network to the cloud/database and displayed it in the doctor's desktop application.

3.2 Software Architecture and Data Processing

The software system includes a Raspberry Pi data-collection program and a physician monitoring program on a desktop. We used Python to write the Raspberry Pi code and interfaces to medical sensors, and Java for the physician monitoring program. The software system collects and digitises sensor data, associates it with each patient, and sends the collected records to the remote monitoring platform.

The data-processing pipeline comprises sensor acquisition, signal/value processing, validation of acquired measurements, patient identification, data transmission, cloud/database storage, and visualisation. The monitoring application reads out the stored measurements and displays the patient's physiological data to the specialist doctor. GPS-based visualisation of the patient location is also possible.

3.3 Sampling and Calibration Procedures

For reproducibility, define the sampling interval and acquisition rate for each sensor based on the actual experimental setup. We set up and calibrated each sensor before data acquisition, and validated the sensor readings against a reference or conventional measurement device where appropriate. We validated heart-rate and blood-pressure data using traditional devices, while validating GPS readings using GPS data from cell-phone GPS services. We used the experimental measurements above to validate the proposed system's agreement with the reference measurement for each parameter.

Document calibration for each sensor individually, including the reference device, the number of measurements, calibration conditions, and the correction and/or filtering algorithm used on the raw signal. Do not claim to use any other calibration algorithm than those in fact used in the experiments.

3.4 Pulse Rate Sensor

It is an optical sensor that connects to the finger and uses the light signal received from the finger to regulate the heartbeat. A pulse wave is a change in blood vessel volume that occurs when the heart pumps blood, and a pulse sensor detects this volume change [19]. Depending on the measurement method, photoelectric pulse wave sensors are classified into two types: transmission and reflection. Transmission types measure pulse waves by emitting red or infrared light from the body's surface and detecting changes in blood flow as a change in the amount of light transmitted through the body during heartbeats [20].

Table 1. Specifications of the Heartbeat [11]

Maximum Ratings	Vcc	(3 – 5.5) V
	I max (Maximum Current Draw)	< 4 m A
	V out (Output Voltage Range)	0.3 V to V cc
Wavelength	LED Output	565 nm
	Sensor Input	525 nm
Dimensions	L×W (PCB)	15.8 mm(0.625")
	Lead Length	20 cm (7.8")

The photodetector picks up a large DC signal representing residual arterial and venous blood, as well as bloodless tissue. The AC signal represents the arterial pulse (a small part of the detected signal, 1%) [21], [22]. By communication protocol between controllers, we collect data and transfer it from sensors to the doctor's monitoring system.

3.5 Blood Pressure

The blood pressure sensor is a non-invasive device that measures human blood pressure. It uses the oscillometric method to determine systolic, diastolic, and mean arterial pressure [23]. This project uses a Raspberry Pi as a gateway to display blood pressure values online. The results showed that the design can transfer data from the blood pressure detector to the monitoring system on the doctor's computer over the network using a USB TTL serial cable connected directly to the Raspberry Pi [24], as shown in Figure 2.

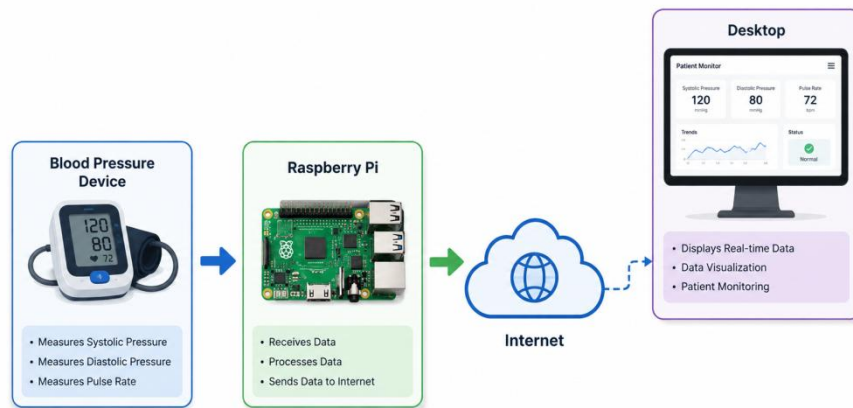


Figure 2. Blood Pressure Software

3.6 Blood Sugar Monitoring

Using a glucose meter, blood glucose monitoring detects the concentration of glucose in the blood (glycemia). A blood glucose test typically involves piercing the skin (usually the finger) to extract blood, after which most systems detect an electrical characteristic and use it to calculate the blood glucose level. Proteus PCB design software can create electronic circuits and circuit boards [25]. The ISIS Intelligent Schematic Input System (Intelligent Switching Input System) is an environment for designing and simulating electrical circuits. The component collection includes over 10,000 circuit components and 6000 Prospective simulation models. Make your components and add them to the collection [26]. Proteus 7.0 relies heavily on circuit simulation. It combines an analogue simulator kernel from SPICE3f5 with an event-driven digital simulator. Use Proteus 7.0 to simulate the interaction between software running on a microcontroller and any analogue or digital electrical device connected to it [27].



Figure 3. Glucose Monitoring Using Raspberry Pi.

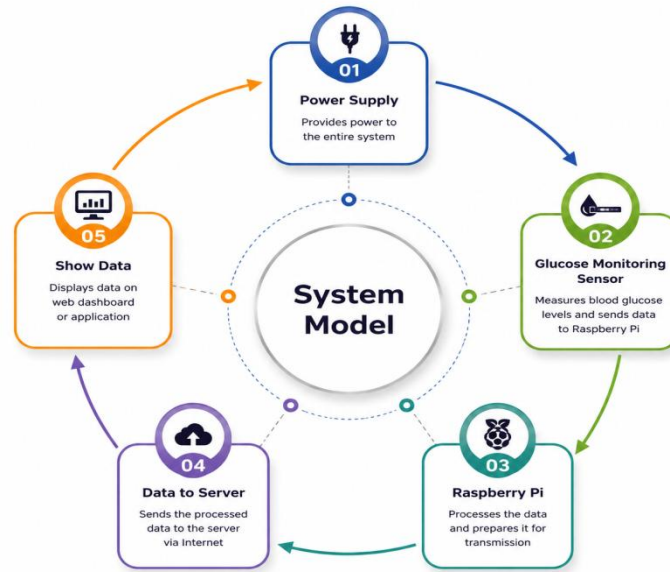


Figure 4. Glucose Level Monitoring Using Raspberry Pi

3.7 GPS (NEO-001-6M)

The system reports any excess or deficiency to the vulnerable person's family using photoplethysmography-based pulse monitoring and intermittent carrier-pulse monitoring. Also, it helps us locate a patient if he is outside the home and suffers from severe Alzheimer's and severe forgetfulness, so he is added to the work. Notification of a low and abnormal pulse rate must be sent to the IoT server, along with the carrier's GPS location obtained from a GSM-GPRS unit mounted on the patient's arm or other central device, so that the patient's location is known if he moves from one location to another unexpectedly [28].

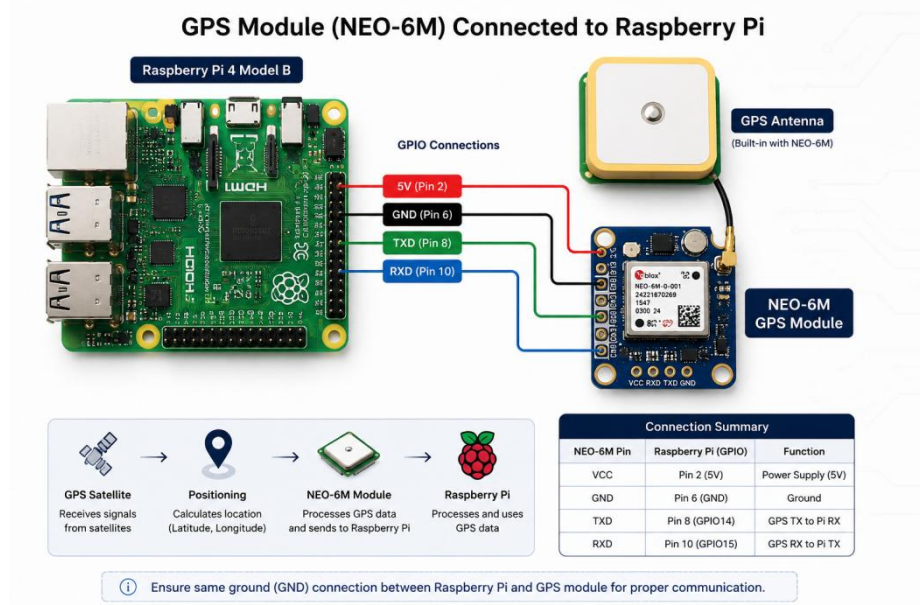


Figure 4. GPS Structure.

The NEO-6M GPS module is a compact and efficient Global Positioning System receiver designed to provide accurate location information. It incorporates a $25 \times 25 \times 4$ mm ceramic antenna that enhances satellite acquisition and tracking performance. The module includes power and signal status indicators, allowing users to monitor its operational condition easily. In addition, a built-in backup battery preserves essential positioning data when the primary power source is disconnected unexpectedly, ensuring faster reconnection and improved reliability during subsequent operation [29].

4. Experimental Result

The proposed healthcare monitoring system estimates the following sensing parameters: heart rate, blood pressure, blood glucose, body temperature, blood oxygen saturation (SpO₂), and the patient's GPS-based location. As described above, the experimental validation results published in this paper consider only these parameters for which measurement results and reference comparisons are available – heart rate, blood pressure, blood glucose, and GPS location. The remaining two sensing modules (body temperature and SpO₂) are part of the proposed healthcare system architecture, but this paper does not present quantitative validation results for them. An experimental evaluation against reference medical instruments and a larger number of test patients is needed to quantify the accuracy of these measurement criteria, as shown in Figure 5.

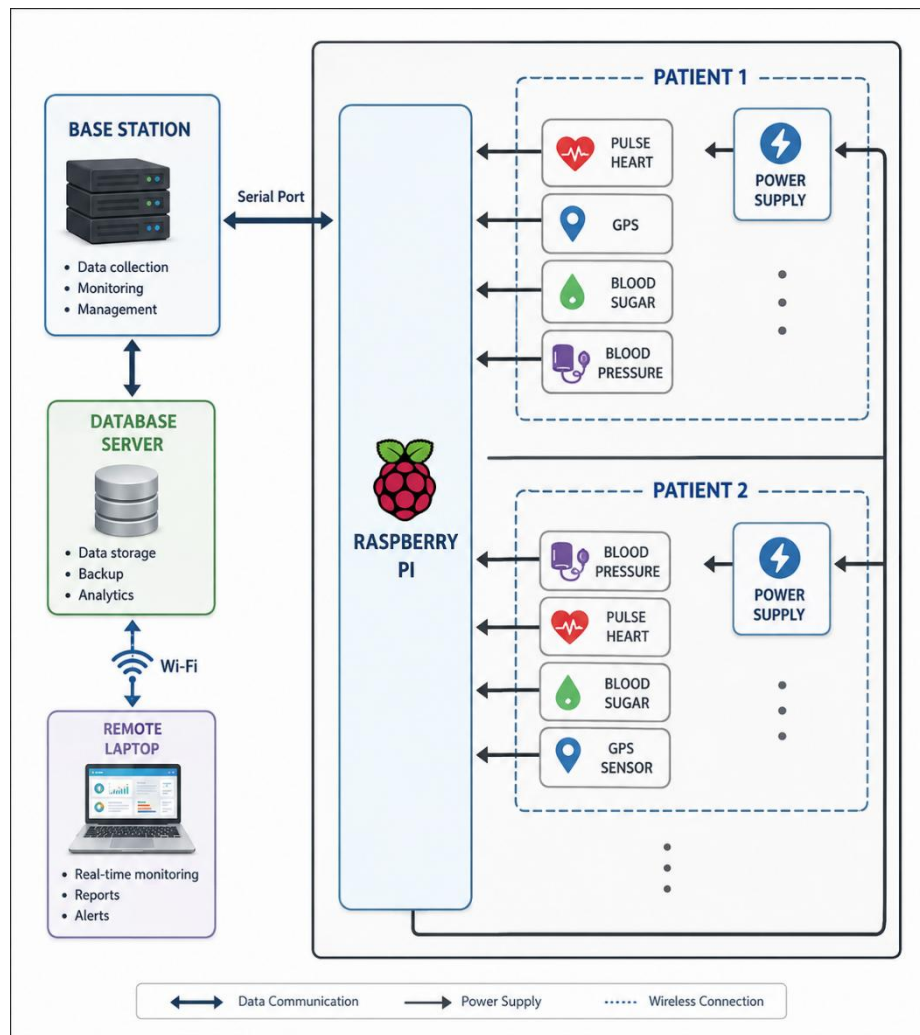


Figure 5. Block Diagram of System Hardware.

4.1 Pulse Rate Measurement

The outcomes are shown on the doctor's desktop application and on the device screen in the monitoring room. Two patients make up the case study implemented in practice. The table below shows each patient's heartbeat rate results. A common (standard) heart rate measuring tool was also used to assess the patient's heartbeat rate [30].

Table 2. Results of Heartbeat for Sensor and Original Device

Name Patient	Age	Heart-Beat Rate(sensor)	Heart-Beat Rate(device)
Patient1	13 years	78 BPM	77 BPM
Patient2	23 years	81 BPM	78BPM

The output values were closed between the sensor and the monitoring device.

4.2 Blood Pressure Analyses

The results are displayed on the monitoring room device screen and in the doctor's desktop application. This case study includes two patients. The table summarises each patient's blood pressure readings. The patient's blood pressure was also measured using a common (standard) blood pressure monitor for comparison, as shown in Table 3.

Table 3. Results of Blood Pressure for Sensor and Original Device

Name Patient	Age	Blood Pressure (sensor)	Blood Pressure (device)
Patient1	13 years	116/77	117/78
Patient2	23 years	120/79	122/80

The sensor and reference device collected the output values.

Experimental Validation and Number of Participants: The experimental evaluation was conducted as a preliminary proof-of-concept study of the monitoring system. Two patients were included in the comparative evaluation of heart rate and blood pressure measurements. The proposed sensor measured 78 and 81 bpm for heart rate, compared with reference measurements of 77 and 78 bpm. Similarly, the proposed system measured 116/77 and 120/79 mmHg, compared with reference measurements of 117/78 and 122/80 mmHg.

These measurements show good agreement between the prototype system and the reference system under the testing conditions. However, because of the small number of participants, the results cannot be statistically generalised to a broader patient population. Therefore, the reported results should be viewed as a feasibility study of the measurement system rather than a clinical validation comparing results to reference systems. The true clinical accuracy and reliability of measurements need to be established in a larger cohort of patients through repeated measurements and statistical analysis.

4.3 Blood Glucose Measurement

The proposed system comprises an optical NIR-based glucose-monitoring module integrated with the Raspberry Pi computing platform. The sensing process involves measuring an optical signal at the measurement site, conditioning the signal, and converting it into a numerical value reported to the physician monitoring application. The sensing process should be sufficiently documented (sensor type, optical wavelength, photodetector specifications, sampling setup, signal-conditioning circuit, and the conversion algorithm between the measured optical signal and glucose value) to allow independent reproduction.

The prototype experimental evaluation reports the following glucose measurements: 103, 79, 105, 115, for four measurement days. However, the current investigation did not include a sufficiently well-documented comparison with a reference device on these measurement days. Therefore, these values are reported as part of a prototype validation of the measurement module's operation rather than as clinically accurate measurements.

The authors did not report a detailed calibration and validation procedure comparing the proposed sensor to a reference glucose meter, with an independently acquired calibration dataset and subsequent validation dataset, to support quantitative claims about the accuracy of the reported glucose measurements, the sensor's precision, or the device's clinical equivalence.

Future work will include systematic calibration and validation with a substantially larger number of paired measurements, repeated measurements at different glucose levels, and statistical analysis of sensor accuracy, as shown in Table 4

Table 4. Prototype Blood Glucose Measurements

Days	Glucose Level
1	103
2	79
3	105
4	115

4.4 Statistical Analysis

We obtained quantitative measures of agreement between the Proposed System and the reference devices by calculating error metrics for the available comparisons: MAE, RMSE, standard deviation (SD), and the Pearson correlation coefficient for heart-rate and blood-pressure measurements. MAE quantifies the average error magnitude, giving an overall sense of error size. RMSE places more weight on larger errors. The standard deviation describes the spread of the errors, whilst the Pearson correlation coefficient describes the linear relationship.

For heart rate, the proposed system values were 78 and 81 bpm; the reference device values were 77 and 78 bpm, respectively, giving absolute errors of 1 and 3 bpm for the former and an MAE of 2 bpm; the RMSE was approximately 2.24 bpm. Values for blood pressure (systolic) were 116 and 120 mmHg for the proposed system and 117 and 122 mmHg for the reference device, resulting in an MAE of 1.5 mmHg and an RMSE of approximately 1.58 mmHg; values for the diastolic pressure were 77 and 79 mmHg compared with 78 and 80 mmHg, giving the proposed system an MAE and RMSE of 1 mmHg. Although these errors appear small, the very small number of comparisons limits their statistical significance. These metrics should be interpreted only as preliminary descriptive values and should not imply actual clinical accuracy or performance. More meaningful insights can be gained when paired comparisons are obtained from significantly more measurements. Future testing would therefore repeat measurements on more individuals with a more diverse set of test subjects.

4.5 GPS (NEO-001-6M)

The application window contains two buttons that show the patient's name and location. We conducted a case study involving two patients. Table 5 tabulates the GPS location results for each patient, with measurements also compiled using the standard Google Maps mobile application for different patients.

Table 5. Performance of Mobile-Phone Standard GPS and Implemented System.

Patient Name	Mobile-Phone Standard GPS	Implemented System
Patient1	36.401165, 43.144465	36.401165, 43.145687
Patient2	36.377474, 43.149250	36.377435, 43.149379

5. Discussion

The results show that the IoT-based health monitoring system provides reliable, accurate measurements of vital signals such as heart rate, blood pressure, blood glucose level, body temperature, SpO₂, and the patient's location. By comparing the results with a conventional medical device, we see a strong correlation, and the results are acceptable. The results support that the initial test set demonstrates the architecture's potential viability. The preliminary test set used in this initial proof-of-concept demonstration showed measurements very close to the reference measurements under the conditions in which they were performed. Due to the small sample size, these results cannot be interpreted as evidence of clinical validity or generalizability.

The novelty of this work does not stem from using Raspberry Pi, IoT connectivity, and medical sensors in a single framework, since existing healthcare monitoring platforms have studied these features. This work adds to them the integration of multiple physiological monitoring features, namely heart rate, blood pressure, blood glucose, body temperature, blood oxygen saturation and patient location based on a GPS device, in a single Raspberry Pi monitoring platform. In particular, this work combines a blood pressure and blood glucose monitoring device with other vital-sign monitors to transfer patient data to a doctor-oriented, Windows-based graphical user interface through an IoT-enabled communication infrastructure and cloud system.

Therefore, this integration provides a single interface that facilitates the acquisition, transmission, and remote visualisation of multidimensional patient data, rather than monitoring each measurement function separately.

As a result, the proposed work contributes mainly through architecture and integration rather than a new sensing technology and its corresponding sensing approach. Although the experimental results are promising, a larger patient sample and comparisons with other multi-parameter healthcare systems are needed to characterise the system's clinical performance and how it differs from previously proposed Raspberry Pi/IoT-based healthcare monitoring systems.

Our Desktop application will help visualise and control patients' data in real time. Another major contribution is integrating blood pressure and blood glucose monitoring within the same platform while maintaining compatibility with other biomedical sensors. The developed architecture allows flexible expansion, and the combination also supports the development of cost-effective monitoring systems instead of conventional medical equipment. The research concluded that low-cost embedded computation platforms like Raspberry Pi can sustain patient monitoring.

These results suggest that this kind of system is valuable for modern smart health care environments. However, further clinical trials should be conducted to test its accuracy across different patients and diseases. Future work can further improve this system by incorporating Artificial Intelligence for monitoring and predictive analysis, strengthening cybersecurity, and adding medical sensors and wearable devices for holistic monitoring.

5.1 Limitations

Although the proposed healthcare monitoring system shows potential and delivered promising results, we should acknowledge a few limitations: First, we evaluated performance with a limited number of volunteers, which may affect the results' generalizability to wider and more diverse communities. Second, although our device achieved excellent agreement with traditional clinical tools, we did not evaluate its performance under long-term monitoring or in large-scale clinical trials. Another limitation is that the system relies on a secure,

stable internet connection to transmit data to the cloud and physician app in real time, which can cause data loss if the network fails.

Currently, our implementation emphasises sensor data acquisition, remote access, and basic alerting rather than intelligent functions for disease diagnosis or predictive analytics for health status.

Lastly, although we included security measures, we need to develop a more comprehensive data security and privacy solution, including encryption, data access controls, and cybersecurity standards, to meet modern clinical needs.

6. Conclusion

This work designed and developed an IoT-based health monitoring system using a Raspberry Pi and an array of sensors to detect patient heart rate, blood pressure, blood glucose, temperature, blood oxygen saturation (SpO₂), and physical location (using GPS). The implementation shows how low-cost hardware, wireless communication protocols, and cloud services can be combined to create a single system that provides ongoing, real-time health updates to health care providers. Experimental results show that the proposed system produced measurements close to commercial medical instruments, confirming the system's reliability and efficiency. Moreover, integrating multiple physiological sensors on one platform can provide whole-body information rather than a single sensor reading, improving clinical decision-making. Another novelty is integrating blood pressure and blood glucose monitoring on the same IoT platform, providing an efficient, low-cost alternative for these conditions while reducing equipment cost and patient effort. Furthermore, cloud-based monitoring with a desktop application offers real-time access and management of patients' health data while maintaining privacy and enabling remote patient monitoring with higher availability and less data loss. In conclusion, the presented work shows that using IoT with Raspberry Pi is a feasible alternative to traditional, costly monitoring instruments and does not compromise measurement accuracy. In future, we aim to improve the system using AI/ML for disease prediction, expand the platform with additional medical sensors, improve data security and privacy, and create a mobile monitoring system for better feasibility and wider adoption.

Based on the results, the system designed in this paper can implement several physiological monitoring functions, such as heart rate, blood pressure, blood glucose, body temperature, and SpO₂ monitoring, as well as GPS-based location monitoring, under the Raspberry Pi-based architecture. The experimental results presented in this paper mainly confirm the proposed system monitoring functions of heart rate, blood pressure, blood glucose, and GPS location monitoring. The results presented should not be relied upon for a quantitative assessment of all integrated physiological parameters, particularly body temperature and SpO₂, which have not yet undergone the necessary physiological tests using reference medical instruments and larger experimental groups.

Conflicts of Interest

"The authors declare no conflicts of interest".

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