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PREDICTIVE ANALYTICS FOR PATIENT MANAGEMENT SYSTEM USING IOT

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Highlights:

- Patient health care is a tremendous pressure on hospital management in urban areas.
- Therefore, the development of IoT (Internet of Things) based patient monitoring systems allows doctors to obtain patient data from remote locations.
- The Internet of Things is an evolving technology that takes healthcare to the next level by providing affordable, reliable, and convenient devices that can be carried or embedded with patients.
- Data is collected using sensors and sent to the cloud via IOT channels, where both patients and doctors can access the data (real-time and historical) through a variety of devices.

Abstract: Lack of health care or inaccessibility of doctors and caregivers is a major concern. Patient health care puts tremendous pressure on hospital management in urban areas. Therefore, the development of IOT (Internet of Things) based patient monitoring systems allows doctors to obtain patient data from remote locations. The Internet of Things is an evolving technology that takes healthcare to the next level by providing affordable, reliable, and convenient devices that can be carried or embedded with patients. There is a growing interest in wearable sensors and medical devices. Therefore, wearable monitoring systems will take patient monitoring to a new level. The IOT allows various devices to be connected over the Internet. Data is collected using sensors and sent to the cloud via IOT channels, where both patients and doctors can access the data (real-time and historical) through a variety of devices. Any deviations from the norm will send alerts to both doctors and patients. This helps healthcare providers monitor a large number of patients at the same time.

Keywords: IOT healthcare; COVID; Health monitoring; Remote patient monitoring; WHO

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1. Introduction

The COVID-19 pandemic has placed unprecedented demands on healthcare systems globally, with a significant proportion of patients requiring continuous monitoring to manage their symptoms and prevent complications. As of July 2024, statistics from the World Health Organization indicate that over 150,000 COVID-19 patients need ongoing observation, highlighting the strain on hospital resources and the critical need for innovative solutions (WHO., 2024).

Traditional hospital settings are often overwhelmed, making it challenging to provide continuous care to patients who do not require intensive care but still need close monitoring. This paper proposes the development of an IoT-based remote monitoring system to address these challenges effectively. By integrating non-invasive sensors capable of monitoring vital signs such as heart rate, blood pressure, and body temperature, the system aims to enable real-time data collection and transmission via IoT gateways over wireless connections. This approach supports the simultaneous monitoring of more than 500 patients, enhancing healthcare providers' ability to remotely assess patient conditions and intervene promptly when necessary. The system's design focuses on scalability and accessibility, ensuring it can be deployed in various healthcare settings including hospitals, temporary care facilities, and remote clinics. It aims to optimize integration with existing healthcare infrastructure such as electronic health records (EHR), facilitating seamless data flow and improving overall care coordination.

Moreover, the system aims to be cost-effective and sustainable, leveraging widely available IoT technologies to minimize implementation costs and maintenance requirements. By achieving these objectives, the proposed system seeks to improve healthcare efficiency by reducing the burden on hospital resources, enabling healthcare providers to allocate resources more effectively. Ultimately, the system aims to contribute to better patient outcomes during the current healthcare crisis and serve as a valuable tool for remote patient monitoring beyond the pandemic, demonstrating its potential to transform healthcare delivery through technology-driven innovation.

2. Related Works

2.1 Machine Learning and AI in Healthcare

Machine learning and AI technologies have been pivotal in transforming healthcare monitoring systems. Rathee et al., (2021) explored various machine-learning strategies for classifying COVID-19 patients, highlighting how these technologies can enhance the accuracy and speed of diagnosis. El Zouka & Hosni, (2021) further emphasized the integration of neural networks and fuzzy systems into healthcare models, enabling smarter and more efficient monitoring.

2.2 IoT in Healthcare

The Internet of Things (IoT) is a critical component in modern healthcare systems, providing innovative solutions and addressing challenges such as mobility, availability, and resource constraints (Alvarez Aldana et al., 2021). (Otoom et al., 2020) proposed an IoT framework for real-time symptom data collection, facilitating the early identification of suspected COVID-19 cases. Similarly, (Taiwo & Ezugwu, 2020) suggested using a remote smart home healthcare support system (ShHeS) for patient monitoring and medication management, allowing healthcare professionals to perform remote diagnostics.

2.3 Real-Time Monitoring and Predictive Models

IoT-assisted architectures have been developed for detecting specific health indicators, such as the QRS complex in ECGs, regardless of patient age or physiological features (Rodríguez-Jorge et al., 2021). (Amarasingham et al., 2014) discussed the creation and validation of predictive models for clinical practice, marking the beginning of real-time point-of-care predictions. Kavya et al., (2023) highlighted the time and expertise required for individual patient monitoring, which is not always feasible for physicians.

2.4 Distributed and Remote Monitoring Systems

Distributed monitoring architectures offer consensus mechanisms that aggregate data for more accurate results (Alex et al., 2016). Naji et al., (2022) proposed access-monitoring services for patients with mild to moderate COVID-19 symptoms, reducing contact between healthcare workers and patients and minimizing infection spread. (Yew et al., 2020) developed an IoT-based remote patient monitoring system that ensures real-time ECG integrity using Message Queuing Telemetry Transport (MQTT), which supports both real-time and store-and-forward modes.

2.5 Smart Devices and Data Transmission

Hanoon & Nouman, (2021) introduced Arduino-based devices with sensors that send data to cloud servers, allowing for faster data access and extensive processing. Vibhute et al., (2019) noted that smart machines significantly improve healthcare system efficiency by evaluating machine-generated reports with minimal human intervention. Paudel & Neupane, (2019) described an IoT-based patient monitoring system that uses sensors to collect real-time data and transmit it to cloud servers for analysis.

2.6 Portable and Remote Physiological Monitoring

Portable physiological monitoring frameworks based on IoT continuously check vital signs, facilitating remote data collection and transmission to prevent disease spread and provide accurate diagnoses (Hafsiya & Rose, 2021). (Priambodo & Kadarina, 2020) emphasized the importance of remote patient monitoring during the COVID-19 pandemic, allowing for the measurement of physiological parameters and data transmission to servers.

2.7 Healthcare Data and Early Detection

Healthcare data from various sources, including smartphones, wearable sensors, patient records, and clinical reports, can enable quick decision-making for the early detection of serious illnesses and pandemics (Kaur et al., 2021). Shaikh et al., (2017) discussed the concept of IoT in connecting devices with embedded electronics to existing internet infrastructure, supporting projects like smart cities, smart homes, intelligent transportation, and patient monitoring systems.

In summary, the integration of machine learning, AI, and IoT technologies into healthcare systems has significantly enhanced patient monitoring, data collection, and disease detection. These advancements offer promising solutions for real-time monitoring, remote diagnostics, and efficient healthcare delivery.

3. Methodology

The system we propose is an IOT-based health monitoring system that enables remote monitoring of multiple COVID patients via the Internet. The system uses heart rate sensors, temperature sensors, and blood pressure sensors to monitor a patient's heart rate, temperature, and blood pressure. The system then sends this data over the internet using Wi-Fi by connecting to a Wi-Fi internet connection. Data is sent and received via IOT from the IOT

Gecko platform for remote display of patient data. The entire system is operated by microcontroller-based circuitry. If an abnormality is detected in the patient's health, or when the patient presses the emergency help button on the IOT device, an alert will be sent remotely via IOT to the doctor. It is mounted on the patient's bedside and constantly sends patient health data over the Internet, allowing doctors to remotely monitor multiple patients and urgently treat them as required.

This system allows:

- The doctors monitor patients remotely without risk of infection.
- A single doctor can monitor many patients at a time.
- Instant alerts in case of health fluctuations or emergencies.

The block diagram of IOT COVID patient health monitoring is shown in **Figure 1**.

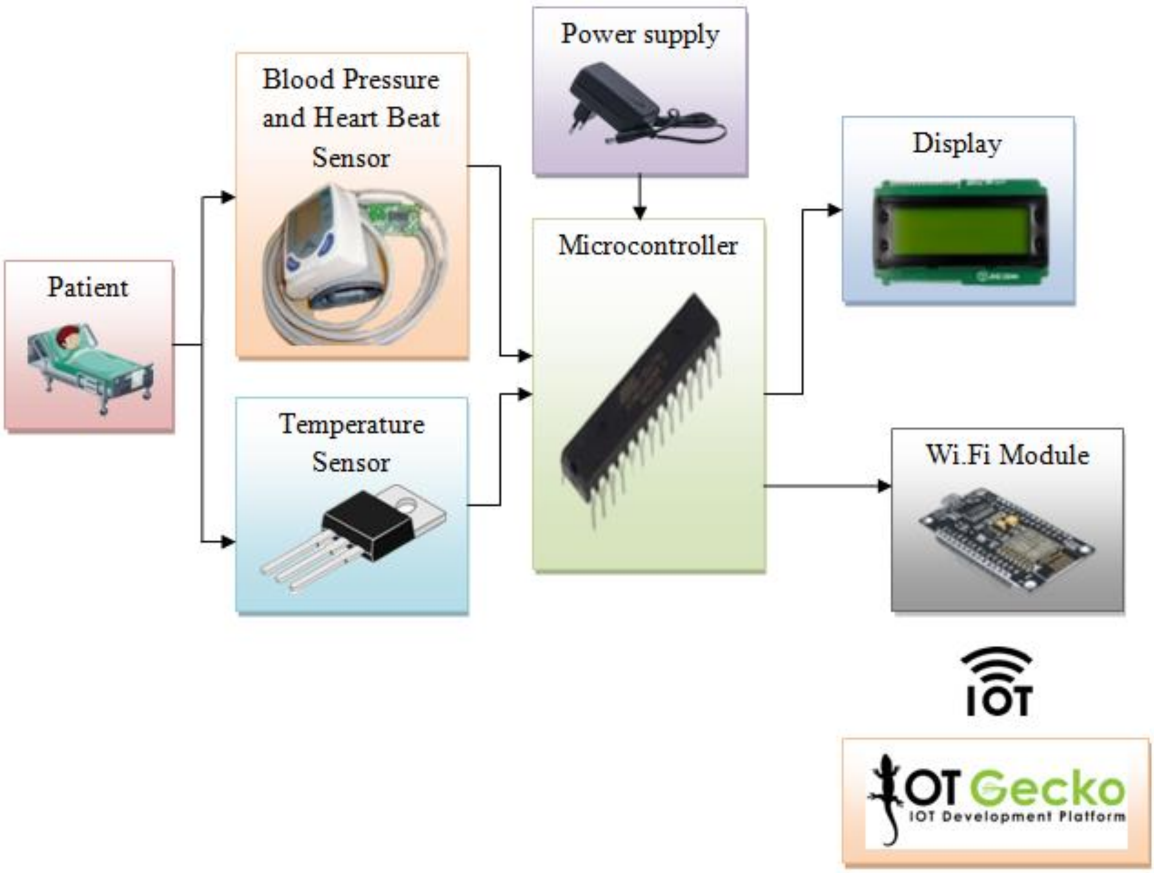

Figure 1. Block Diagram of IOT Patient Health Monitoring System

3.2. ATmega Microcontroller:

The ATmega328 microcontroller offers high performance with its ability to execute many instructions in a single clock cycle, providing a throughput of almost 20 MIPS at 20MHz. It is designed for low-power operation, which is essential for battery-operated or continuous-use devices. It includes 32kB of programmable FLASH, 1kB of EEPROM, and 2kB of SRAM, sufficient for storing and processing the data from multiple sensors. It can perform general-purpose tasks similar to a computer, making it suitable for a variety of applications. The ATmega328 was chosen for its high performance, low power consumption, and sufficient memory, which are critical for a real-time, continuous monitoring system. Its versatility ensures that it can handle various tasks required for the health monitoring system.

3.3. Temperature Sensor:

The LM35 temperature sensor provides a highly accurate and precise temperature reading with a linear output voltage directly proportional to the Celsius temperature. It is internally calibrated to Celsius, requiring no external calibration. It operates with very low power, requiring only 60 µA, making it suitable for continuous monitoring. Additionally, it can operate in a wide temperature range from -55°C to 150°C, covering the necessary range for patient monitoring. The LM35 was selected for its precision, low power consumption, and wide operating range, ensuring reliable and accurate temperature monitoring essential for detecting fever, a key symptom of COVID-19.

3.4. Heart Beat Sensor:

The heartbeat sensor is based on photoplethysmography, specifically the reflective type, which is suitable for non-invasive monitoring. It provides accurate measurement of heart rate by detecting changes in blood volume. Additionally, the output can be easily interfaced with the microcontroller for digital processing. The heartbeat sensor using reflective photoplethysmography was chosen for its non-invasive nature, accuracy in heart rate detection, and ease of integration with the microcontroller for continuous patient monitoring.

3.5. Blood Pressure Sensor:

The compact design of the blood pressure sensor fits over the wrist, making it comfortable and easy to use. It features automatic compression and decompression, ensuring accurate and consistent readings. The sensor provides serial output data at a 9600 baud rate, suitable for real-time processing, and operates at a regulated +5V, 200mA, making it compatible with the microcontroller. The selected blood pressure sensor's compact design, automatic operation, and compatibility with the microcontroller make it ideal for continuous, non-intrusive blood pressure monitoring.

3.6. Wi-Fi Module:

The ESP8266 was selected based on its embedded Wi-Fi capabilities, which provide seamless connectivity to the internet, crucial for real-time data transmission in healthcare monitoring systems. Operating at a reliable 2.4 GHz frequency, it ensures robust communication. Its integration with the microcontroller via UART interface is straightforward, facilitating easy setup and deployment. These features make the ESP8266 ideal for enabling continuous and real-time data transmission to remote monitoring systems, supporting efficient healthcare monitoring and management of patient data.

3.7. Display Devices:

The selection criteria for LEDs and LCDs were based on specific functionalities crucial for the health monitoring system. LEDs were chosen for their low energy consumption, long service life, and high visibility, making them ideal for indicating status alerts in a continuous operation environment. On the other hand, LCDs were selected for their ability to display detailed information with a 16x2 character capacity, suitable for presenting comprehensive data to healthcare providers. Their compatibility with the system’s power requirements (4.7V to 5.3V) and flexibility in operating modes (4-bit and 8-bit) ensure seamless integration with the microcontroller, supporting efficient and reliable user interaction. Together, the combination of LEDs and LCDs provides a balanced solution for clear status indication and detailed data display in the health monitoring system.

3.8. Software Description

The ATmega Microcontroller is like the heart of the software. The Arduino project supplies the Arduino Integrated Development Environment, which is used to create and compile the application. Embedded C was used to create the software. The following is the key portion of the programming design: The first step is to connect all of the sensors' output reading points. It will begin to read the sensor measured output once it was programmatically connected. For processing, the received sensor output is saved in the appropriate local register. Each sensor has a set of predefined values, such as minimum, normal, and maximum. If the obtained numbers are below the minimum to normal, the processing will proceed normally. However, if it was maximal and above, it would send a high-priority alarm and notify doctors with particular programming conditions.

The Software can be divided into two sections:

Part 1:

Hardware programming to read the input signals from the hardware (Arduino) system and send them to IOT. The steps involved in programming the hardware can be seen in **Figure 3**.

Part 2:

Retrieving the data stored in IOT and displaying it from the server

Step 1:

- Create an Account and Fill some required details.
- Select the Application for which we are going to develop the IOT System.

Step 2:

- Choose your desired layouts for data display.
- The default designs for different applications available in IOT gecko are shown in **Figure 2**.

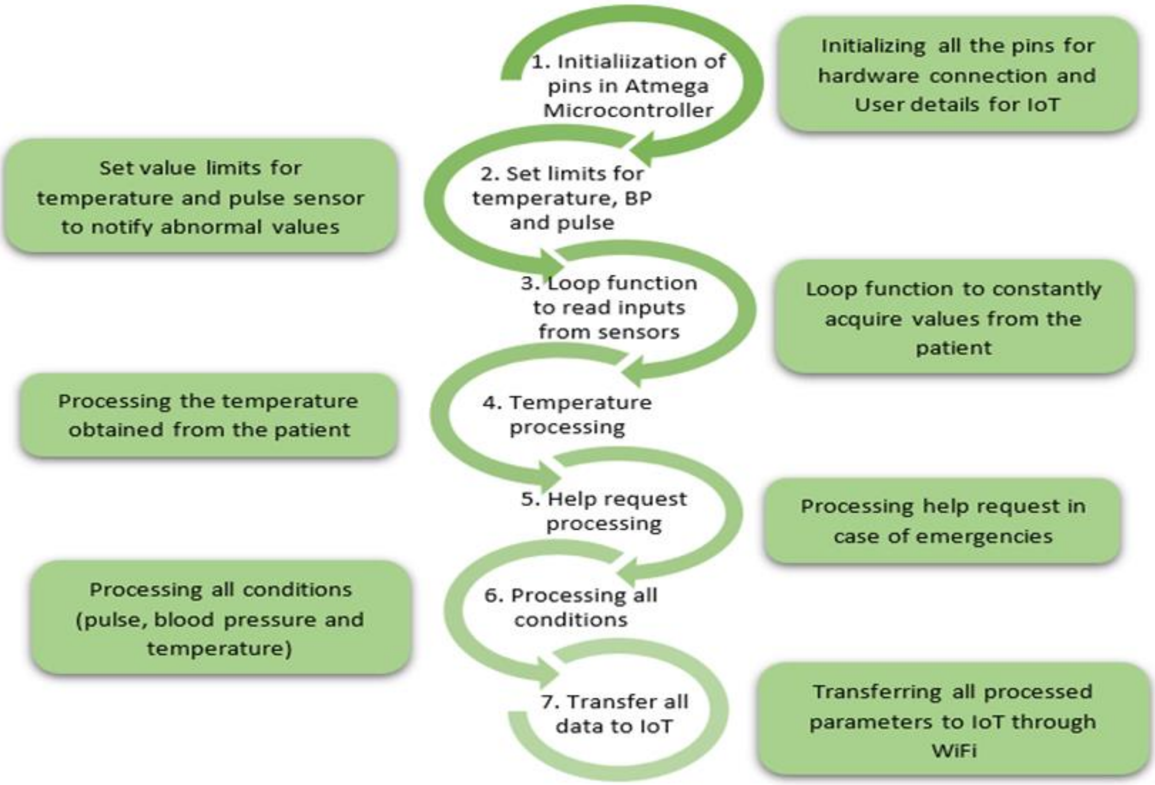

Figure 2. Steps involved in hardware programming

Step 3:

Login Credentials will be sent to the Mail and access the IOT Gecko.

Step 4:

- Easy Integration: Integrate the electronics systems to online servers from Arduino, Raspberry Pi, ARM, 8051, PIC, AVR controllers and more.

4. Results and Discussion

Continuous monitoring through IoT utilizes sensors embedded on the patient to capture vital health parameters such as blood pressure, temperature, and heart rate in real-time. These parameters are displayed on an LCD screen immediately upon power supply activation, as illustrated in **Figure 3**. Simultaneously, the collected data is transmitted via an IoT gateway to a centralized IoT server. Here, it undergoes secure storage and processing, enabling both real-time monitoring and historical data access via the IoT platform. This setup facilitates remote access for healthcare providers to monitor patients' health status effectively and make informed decisions based on comprehensive, up-to-date information.

Figure 3. Output displayed on LCD screen

Healthcare providers, including doctors and nurses, can access this data by logging into a secure account on the IoT platform. Access is typically managed through authentication protocols to ensure patient privacy and data security. Once authenticated, healthcare workers can view the real-time health parameters of their patients remotely.

The IoT platform not only displays real-time health parameters but also allows for historical data retrieval and analysis. This capability is crucial for monitoring trends over time, detecting anomalies, and making informed medical decisions. For example, healthcare providers can track changes in a patient's blood pressure, temperature variations, or heart rate trends, which may indicate worsening or improving health conditions. **Figure 4** typically displays graphical representations of health parameters such as blood pressure, temperature, and heart rate from different individuals. Graphs offer a visual overview that facilitates quick interpretation of trends and patterns. For instance, trends over hours, days, or weeks can be observed to understand the effectiveness of treatments or to identify potential health issues early.

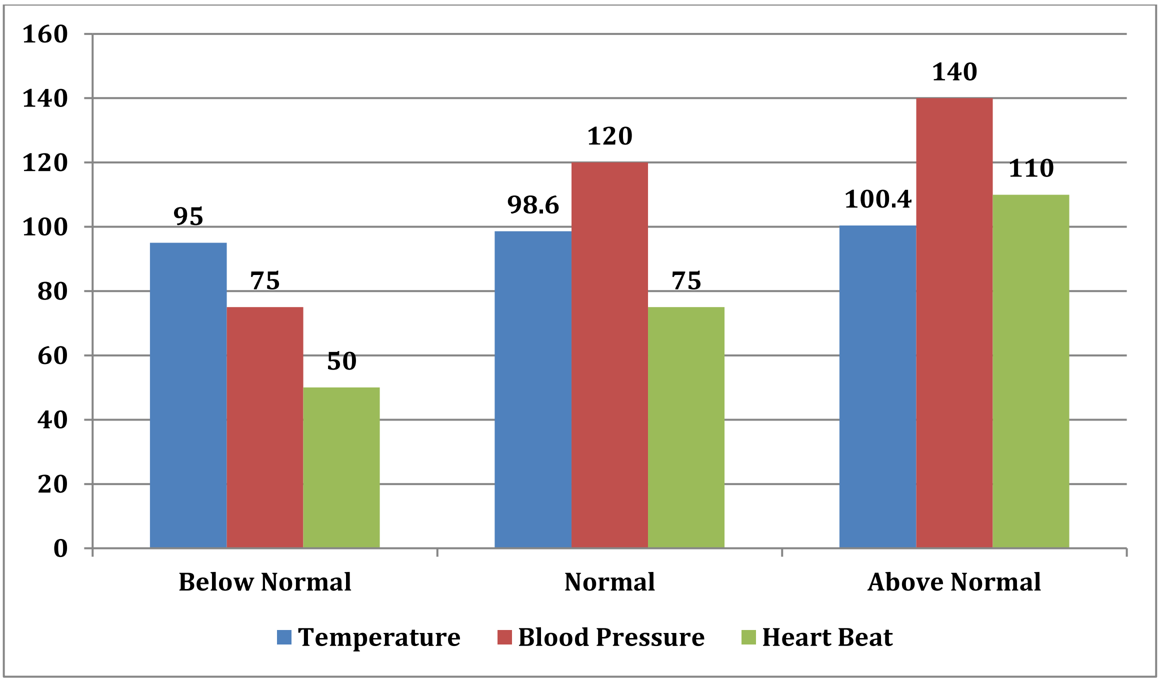

Figure 4. Different outputs obtained from different patients

Figure 5 showcases health parameters displayed on the default IoT Gecko platform interface. This includes a user-friendly dashboard or interface that provides at-a-glance summaries of vital signs. The platform may offer customizable features such as setting thresholds for abnormal readings, generating alerts for healthcare providers, and integrating with electronic health records (EHR) systems for comprehensive patient management.

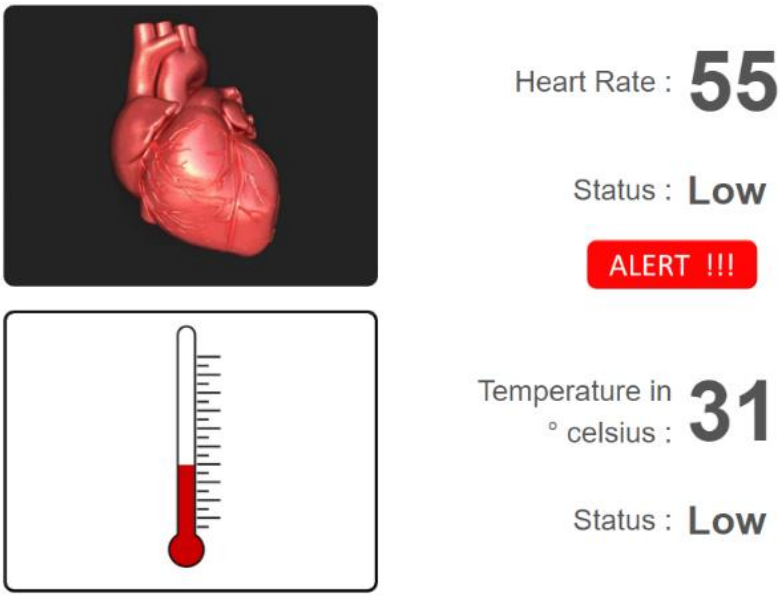

Figure 5. Health parameters displayed on IOT Gecko platform

Table 1 infers data of different individuals which shows varied parameters which can be classified into normal and abnormal ranges and alerts can be sent for abnormal variations in the parameters.

Table 1. Temperature, Blood Pressure and Heart Beat of Various Individuals

	Temperature [˚C]	Blood pressure [mm/Hg]	Heart beat [bpm]
Person 1	37.5	124/82	80
Person 2	36.8	118/79	76
Person 3	36	121/78	72
Person 4	36.3	115/79	71
Person 5	36.7	125/81	78
Person 6	37.3	117/76	83
Person 7	36.4	118/77	77
Person 8	36.9	120/81	73
Person 9	36.6	122/83	74
Person 10	37.2	121/82	85

Temperature unit is in the form of SI unit and is denoted using C (degree Celsius). The blood pressure is measured in mm/Hg (millimetre of Mercury). The heartbeat is measured in bpm (beats per minute).

Comparing this system with other methods, such as traditional manual monitoring or less integrated digital systems, highlights several advantages. Unlike manual methods, which are prone to human error and lack real-time updates, the IoT-based system automates data collection and transmission, reducing reliance on periodic checks and enabling continuous monitoring. This integration of real-time display, remote access, and data analytics underscores the system's effectiveness in modern healthcare monitoring, offering scalable solutions for improved patient care and management.

5. Conclusion

The IoT-based remote patient monitoring system outlined here marks a significant step forward in healthcare technology, particularly in its ability to manage patients remotely amid health crises like COVID-19. By employing sensors to monitor vital signs such as blood pressure, heart rate, and temperature in real time, the system enables early detection of anomalies, facilitating timely medical interventions and improving patient outcomes. Its user-friendly nature, featuring easy setup and access via LCD displays and IoT platforms, ensures usability across diverse patient demographics, including elderly individuals requiring minimal supervision. Looking ahead, future enhancements could include developing a mobile application with robust alert systems for continuous monitoring and expanding the system into wearable devices to offer mobility and comfort. Integration of AI and ML technologies holds promise for predictive analytics, enabling personalized healthcare insights and proactive disease management strategies. These advancements not only promise to revolutionise patient care but also to optimize healthcare delivery by fostering a connected, proactive approach to health management.

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Credit Author Statement

Conceptualization, S.R.; methodology, S.R.; software, S.A.; validation, S.R, and S.A.; formal analysis, S.R.; writing—original draft preparation, S.R.; writing—review and editing, S.A.;

Conflicts of Interest

The authors state that they have no financial or other conflicts of interest to disclose with connection to the current study.

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