https://africanjournalofbiomedicalresearch.com/index.php/AJBR
Afr. J. Biomed. Res. Vol. 27(6s) (December 2024); 334-343
Research Article

Remote Patient Monitoring System for Enhanced Care with IOT Devices

Manoj Sharma[1*], Ankita Kumari[1], Kirti Gupta[1], Yugnanda Puri[1]

[1]Dept of Electronics and Communication, Bharati Vidyapeeth's College of Engineering, New Delhi, India

Abstract: The advancement of digital technologies, especially within the domain of Internet of Things (IoT), has profoundly influenced numerous industries, including healthcare. The IoT's ability to connect and enable communication between various physical devices over the internet improves data interoperability, essential for data monitoring, collection, storage, and visualization. This progress has led to the emergence of innovative methods in healthcare management, where accurate real-time monitoring and data analysis is essential. The current proposal presents an advanced healthcare monitoring system that utilizes IoT technology to track patients' health metrics consistently. This system gathers vital signs and other pertinent health information, sending them wirelessly to a central network via a secure Wi-Fi connection. Consequently, healthcare providers and caregivers can continuously access the latest patient data, allowing for prompt reactions to any anomalies or urgent health signals. The system features a notification system, including SMS and sound alerts, to quickly inform caregivers and healthcare professionals of possible health issues. Ensuring security and privacy is critical in configuring this remote monitoring solution, which employs cloud technology and password-protected access to safeguard the confidentiality and accuracy of patient information. By providing a secure, effective, and user-friendly platform, this IoT-based system seeks to improve the quality of healthcare services, showcasing technology's potential to transform patient care and assistance. This paper explores an IoT-based healthcare monitoring system's development, implementation, and implications, highlighting its contribution to modern healthcare practices.

Keywords- Internet of Thing (IoT), Raspberry pi microcontroller, GSM Modem, ECG Sensor, Temperature Sensor (LM35), Heartbeat Sensor, Wi-Fi module (ESP 8266), L.C.D.

Received:12/11/2024 *Accepted:31/12/2024*

DOI: https://doi.org/10.53555/AJBR.v27i6S.6357

I. INTRODUCTION

Health is a fundamental necessity for a fulfilling life. Yet, various factors, such as insufficient healthcare facilities, pronounced disparities between urban and rural healthcare access, and the absence of medical professionals during critical moments, have raised concerns regarding global health challenges. The World Health Organization describes health as a comprehensive state of physical, mental, and social well-being beyond just the absence of illness. To improve the quality of life with sustainable health, the amalgamation of technologies must be considered with medical science. Realizing these healthcare professionals are adopting themselves with advances in technologies.

The Internet of Things (IoT) advancements can connect many devices that perform useful functions. Through IoT, the data is collected and transmitted to different desired locations, having the expertise to analyze the best way. This technology can play a critical role in medical equipment capable of measuring health-related parameters. So, the health monitoring parameters can now be transmitted to remote locations, establishing a mechanism of interactions between health equipment and doctors situated at remote places. This integration speeds up the process, making it more efficient and flexible, turning to a sophisticated technology for remote health monitoring. Hence, this enables prompt medical responses and treatment efficacy. Further, this integration enables the collating of health data systematically, which would help in assessing health and treatment issues in the future as well. This enhances the issues of managing medical records, especially when treatment involves experts in different countries and different parts of the globe. The same medical records can be available across teams to converge on the best for the patient. Therefore, this bridges the gap in the healthcare delivery system.

IoT-enabled health care framework comprises numerous medical sensors linked to a central machine. This enables real-time monitoring of the individual. Health indicators like body temperature, oxygen levels, cough, heart rate, blood pressure, etc., provide critical information about the patient's health condition. The geolocation tagging with these parameters increases the quality of health care service. This also helps identify any pandemic and provide health care services during pandemic situations. Through IoT technologies, the environment-related parameters and patient proximity can also be monitored and analyzed, which becomes more helpful in contagious disease outbreaks. In the process of developing these technologies, it is imperative to address security and data management to rigorously safeguard against the misuse of personal data. There is a risk that governments might repurpose such platforms for continuous surveillance post-pandemic, aiming to monitor and regulate public behavior, highlighting the need for stringent data protection measures.

II. Related work

The burgeoning field of research in healthcare technology is increasingly directed toward enabling systems to function at an individual level, particularly after a patient has been discharged from the hospital. To ensure the smooth operation of these systems, efforts are being made to rectify any real-time constraints and errors that may arise from using various remote technologies. Over recent years, many IoT applications have been developed to enhance healthcare delivery. The IoT is leveraged for remote monitoring of patients, such as connecting elderly individuals with chronic illnesses to healthcare professionals and resources. There have been implementations of IoT solutions to support individuals with Parkinson's and Alzheimer's diseases, provide emergency management for seniors living alone, manage hospital equipment and patient admissions, and facilitate pre-hospital remote diagnoses for more effective treatment. Specifically for diabetic patients, continuous monitoring of blood glucose levels is essential; data from wearable sensors can be transmitted to healthcare providers or smartphones for ongoing health monitoring.

Development in wearable, lightweight, portable sensors for measuring human physiological parameters was reported by Siam, Yang, and Kamble. Sensors like ECG, EDA, blood pressure, and body temperature get integrated into the Body Sensor Network (BSN). This enables humans to wear the sensor networks while performing routine work [1-3]. Further, many systems were reported for real-time remote monitoring after hospital discharge. These systems make use of communications networks like ZigBee to transmit measured critical health parameters in real time to the team of doctors [10-15].

The use of a LoRaWAN (Long Range Wide Area Network) network infrastructure become a boom in long rage operations. Specifically in rural areas where there is limited cellular network coverage, the "IoT-based Health Monitoring via LoRaWAN" brings the doctor advice near to real-time, reducing the delay and cost as compared to other technologies like GPRS/3G/4G/5G [15-17].

III. System Architecture

The proposed system architecture provides an interactive platform for all stakeholders in the healthcare industry. Through this platform a healthy real-time interaction is enabled among doctors, patients, and attendants. The architecture makes use of a controller like Raspberry Pi for edge computing. Through the controller, the information is interchanged with the loud. This enables patient-specific care extensions at every level. A comprehensive description of the proposed architecture is depicted in Figure 1.

In the innermost layers several sensors measure the patients' critical parameters capable of indicating the adverseness of the health's progress or deterioration. A central hub collects the data, diagnoses initial issues, and sets up the data transmissions in case of some adversity. The data collated in the cloud is used to screen comprehensively about health and use AI/ML algorithms in making decisions. This increases the prediction accuracy and reduces the load on the degree of manual intervention in the continuous monitoring mechanism. All through this process, the relevant information is provided to the patient, his/her attendant, and the doctor. This platform enables integrated communication among them.

The platform has individual dashboards with plenty of features specifically meant for doctors or patients or attendants. For example, the patients can view the parameter matrix and history of prescriptions, book appointments, take consultations, and locate nearby healthcare parameters. Also, he can use an AI-based chatbot for a preliminary health assessment. The health parameters are accessible along with prior medications, improvements, side effects, and complete history, along with real data fetching from the sensors. Based upon these, doctors can prescribe treatments, medicines, exercises, and next follow-up dates and can also inform attendants in case of adversities. This also enables the access of other facilities like ambulances, health care equipment, etc., automatically.

Further, this also has a chemist interface to fetch the new stock of medicines as per prescription. Similarly, the attendant can access all relevant information, doctors' advice, medicine stocks etc. This integrated platform is useful for general patients as well as critical patients. This enables prompt responses to help the patients. The platform ensures real-time data processing with data security, keeping the patient's privacy.

The continuous internet connection becomes the most essential element of the proposed architecture. The system is based upon three main components: the Wireless Body Sensor Network (WBSN), Remote Server, and User interface.
These three act in a well-knitted manner to transmit the data when required based upon the intelligence. Edge computing is restricted due to resource limitations, but it acts as primary decision-making based on the initial data. Cloud computing has plenty of resource availability, which enhances the computing capability. AI algorithms are implemented on the cloud to have a higher degree of accuracy in predictions.

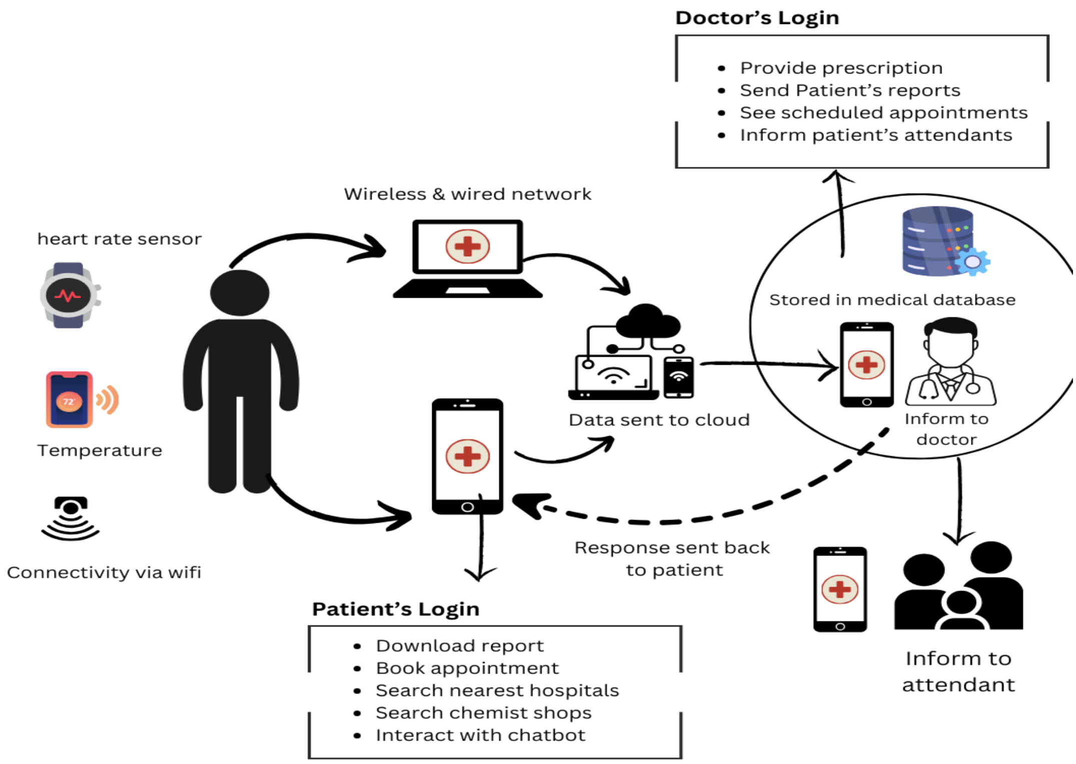


Fig 1: Architecture of the entire system

(I) Wireless Body Sensor Network

Wearable sensors to sense health parameters like blood pressure, ECG, heart rate, oxygen levels, etc., are used to sense these parameters for the patients. The sensors are integrated with WBSN. These sensors gather physiological signals from the patient's body and transmit the data to the base station or gateway server through a Wi-Fi module.

A. DHT11- Temperature and humidity sensor

The DHT11 is a combined temperature and humidity sensor that provides a calibrated digital output signal. Utilizing a unique digital signal-collecting method and advanced temperature and humidity sensing technology, the DHT11 guarantees high dependability and superior long-term accuracy. This device incorporates a resistive humidity sensor and an NTC (Negative Temperature Coefficient) sensor for temperature measurement, all managed by a high-performance 8-bit microcontroller. Table 1 shows the pin specifications of this sensor.

- It can measure relative humidity levels from 20% to 90% RH and temperatures from 0°C to 50°C, providing these readings through a serial digital signal over a single wire.
- The sensor has four pins, one dedicated to serial data communication.
- It interprets pulses of varying durations of ON (TON) and OFF (TOFF) times to distinguish between logic 1, logic 0, the start of a data packet, or the end of data transmission.

Table 1: DHT111 Pin specifications

Pin No.	Pin Name	Pin Description
1	VCC	PS 3.3-5.5V
2	DATA	Digital out
3	NC	Not in use
4	GND	Ground

The DHT11 sensor incorporates a capacitive element for humidity detection and a thermistor for temperature measurement. The capacitive humidity sensor operates on the principle of capacitance change due to moisture level variations between its two electrodes, which have a moisture-absorbent material sandwiched between them. This alteration in capacitance is then converted into digital data by the sensor's integrated circuit, which processes changes in resistance.

The DHT11 utilizes a Negative Temperature Coefficient (NTC) thermistor for temperature detection, whose resistance diminishes with rising temperatures. This sensor is typically constructed from semiconductor materials to ensure sensitivity to minor temperature fluctuations, offering precise readings. Fig 2 shows the real-time data of the patient's temperature and humidity. With a temperature sensing range of 0 to 50°C and an accuracy of ±2°C, alongside a humidity detection range of 20 to 80% RH with a 5% accuracy level, the DHT11 provides reliable data. It outputs readings at a frequency of 1Hz, meaning it delivers one reading per second. Compact in size, the DHT11 operates on a voltage range of 3 to 5 volts and consumes a maximum of 2.5mA during operation.

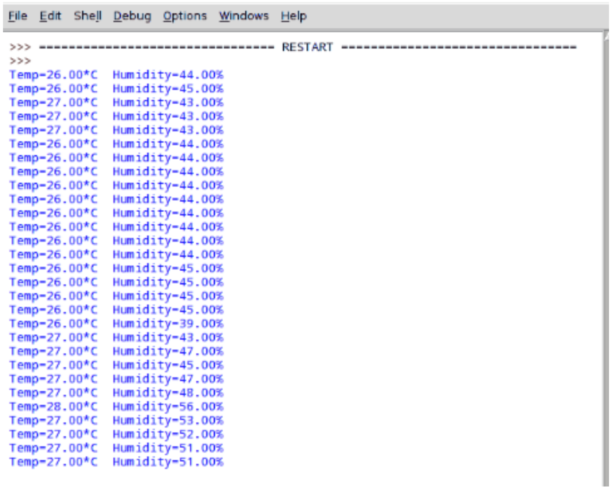


Fig 2: Sensor data of DHT11 sensor

Its compact size and sampling rate made this sensor popular among hobbyists. Some of the sensors that can be used as an alternative to the DHT11 sensor are DHT22, AM2302, and SHT71.

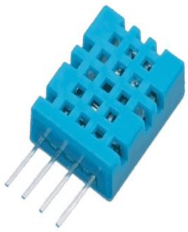


Fig 3: DHT111 Sensor [18]

B. ***MAX30102- Pulse rate and SPO2 level sensor***

The MAX30102 module integrates functionalities for both pulse oximetry and heart rate monitoring. It consists of LED, photodetector, optical components, and electronic circuits. This minimizes the noises and effects of the environment on its performance. The sensor can be integrated with ease. It has a dual power supply working with a 1.8V source for the main operation and a 3.3V power supply for the built-in LEDs. This is communicated via I2C protocol. The device can be shut down with the help of commands at the software programming level, which helps minimize power when not in use.

Key specifications include:

-MAX30102 LED's wavelengths when working at peak efficiency: 660 nm and 880 nm

-MAX30102 Voltage range for LED's power supply: between 3.3V and 5V

-The type of detection signal: reflects light

- Signal output interface: I2C compatible

- Range for communication interface voltage: from 1.8V up to 5V

- Dimensions for the board's mounting hole: 0.5 x 8.5 mm

Table 2: MAX30100 Pin specifications

Pin No	Pin	Definition
1	Vin	1.8V-5.5V
2	SCL	IIC-9L
3	SDA	IIC-SIM
4	INT	MAX30100 INT
5	IRD	MAX30100 IR_DRV
6	RD	MAX30100 R_DRV
7	GND	Ground

The MAX30100, like all optical pulse oximeters and heart-rate sensors, features two high-intensity LEDs—one RED and one IR, each emitting light at distinct wavelengths of 660nm and 880nm, respectively—along with a photodetector.

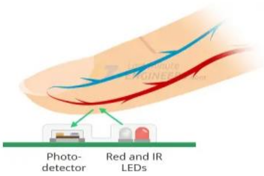


Fig 4: LED and IR lights on MAX30100 [20]

The MAX30100 operates by projecting red and infrared (IR) light into areas of the skin that are thin enough for the light to pass through easily, such as the finger or earlobe, and then measures the light reflected back with a photodetector. This technique, known as Photoplethysmography, is utilized for detecting pulses.

1) Heart Rate Detection:

In arterial blood, oxygenated hemoglobin (HbO2) absorbs IR light, with more absorption occurring when blood has a higher hemoglobin concentration, making it appear redder. With each heartbeat, as blood flows through the finger, the quantity of light reflected back varies, which is captured by the photodetector as a fluctuating waveform. Continuous monitoring and analysis of these changes allow for the determination of the heart rate (HR).

Fig 5: Pulse and spO2 level data

2) Pulse Oximetry Measurement:
The principle behind pulse oximetry is that oxygen-saturated and deoxygenated hemoglobin absorb different amounts of RED and IR light. The absorption levels vary with the oxygen content in the blood, which is graphically represented by the absorption spectra for both forms of hemoglobin (HbO2 and Hb).

C. **Raspberry Pi Microcontroller:**
The Raspberry Pi is a versatile device capable of performing many of the tasks expected of a conventional computer. A microcontroller is typically an integrated circuit designed to govern a part of an electronic system, often managed by a microprocessor. There is some confusion regarding whether the Raspberry Pi qualifies as a microcontroller.

Fig 6: Raspberry PI [21]

Contrary to some beliefs, the Raspberry Pi is a microprocessor, not a microcontroller. It is generally larger, consumes more power, operates at a clock speed ranging from 700MHz to 1.5GHz, and comes with RAM sizes between 1 and 8GB. Unlike microcontrollers, the Raspberry Pi can execute both 32-bit and 64-bit operations.

Microprocessors necessitate an operating system for running complex tasks, requiring significantly more memory. The RAM for microprocessors varies from 512MB to 32GB, while ROM ranges from 128GB to 2TB. In contrast, microcontrollers, built for specific functions, require much less memory, with RAM ranging from 2KB to 256KB and ROM from 32KB to 2MB.

(II) Remote Server
This data is stored in file format at the base station for subsequent access and use. Data retrieval is facilitated by entering the relevant IP address on an end-user device (e.g., PC, laptop, tablet).

(III) User Interface
The GUI component stores, processes, and displays the collected data in graphical and textual formats. It also enables the transmission of SMS alerts to either the physician or the patient's family via a GSM Modem. The IoT system predominantly employs the microcontroller within a Raspberry PI Board, equipped with an LCD and a Wi-Fi module for displaying current health statuses and transaction processes. A buzzer is incorporated to notify caregivers in critical situations. The HTTP protocol is utilized for communication between the Wi-Fi module and the web server due to its simplicity and effectiveness in facilitating communication.

WEB APPLICATION
This web application, built with the MERN stack (MongoDB, Express, React, and Node.js), aims to revolutionize healthcare delivery by providing a secure and efficient platform for patients and healthcare providers.

Key Features:
- **MERN Stack:** Provides a robust and flexible framework for building a scalable and performant web application.
- **Patient Portal:** Secure access to medical records, appointment scheduling, messaging with providers, prescription refills, and health data tracking.
- **Provider Dashboard:** Comprehensive tool for managing appointments, patient records, communication, collaboration with team members, and telehealth consultations.
- **Telehealth Integration:** Secure video conferencing for remote consultations, improving accessibility and convenience for patients.
- **Prescription Management:** Electronic prescription submission and management, streamlining workflows and reducing errors.
- **Appointment Reminders:** Ensures timely attendance and reduces missed appointments.

THE OVERALL WORKFLOW OF THE SYSTEM

STEP 1: SENSOR DATA COLLECTION
Various sensors attached to the patient continuously monitor vital signs and health metrics, such as heart rate, blood pressure, and temperature. Wirelessly connected sensors ensure real-time data collection without restricting the patient's movement.

Step 2: Data Transmission to Patient's Device
The sensor's data is wirelessly transmitted to the microcontroller. Raspberry Pi is used for the same, which is the initial data processing stage. Based on these initial checks, the data is prepared and transmitted to the cloud. Data integrity is kept essentially at this stage as well.

Step 3: Data Upload to the Cloud
The microcontroller sends the health parameters based on processed data frames to the cloud. Clouds act as data storage and computing centers for predictions. Data is analyzed with the help of AI models to detect anomalies and any negative trends in the data to predict insights into the patient's health.

Step 4: Data Access by Healthcare Professionals
Healthcare professionals monitor the data stored in cloud-based servers and reports generated by AL models in the cloud. The access is provided through a login-based platform, which can be accessed either on laptops/phones, etc. Visualization of the data and reports helps healthcare professionals understand and analyze the data easily.

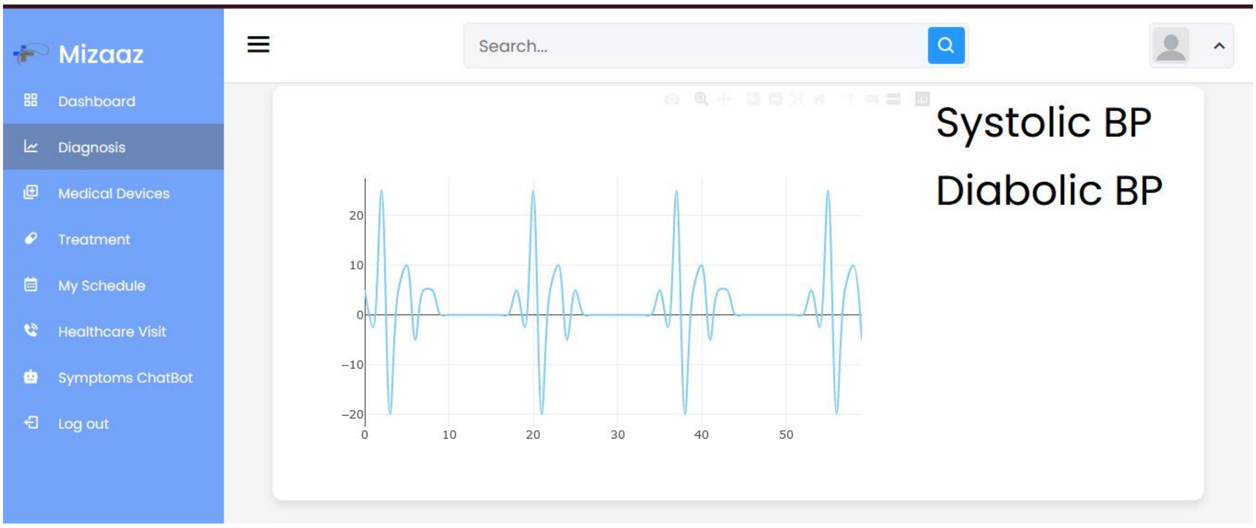
Step 5: Feedback and Prescription
Doctors analyze the reports and data based upon which they send feedback and medical advice along with prescriptions. The cloud-based computing ensures accurate and timely medical advice to patients.

Step 6: Patient Receives Doctor's Feedback
From the cloud server, the doctor's prescription is transmitted to the microcontroller, which ensures the de-framing to represent the feedback in a format readable to the patient. Further, the microcontroller can take controlled actions to order medicines or any medical equipment and raise any alarms needed.

IV. Results and Implementations

Web-based platform is developed to enable efficient healthcare access for patients and healthcare providers. It is a central access place, providing various login-based access to stakeholders. The **Frontend uses** JavaScript ReactJS for developing dynamic and interactive graphical user interfaces. For **Backend** JavaScript, Nodejs is used for server-side scripting and developing the required APIs. MongoDB, a NoSQL database, is used to help future-related scalability. Express.js is also used in middleware and routing like authentications, encryption, data visualization, etc.

Web Application: Key features
The developed healthcare platform, backed by IoT-enabled sensor networks, provides easy-to-access loin-based user types for patients, doctors, and attendants. Each of these logins provides special features for the respective user.



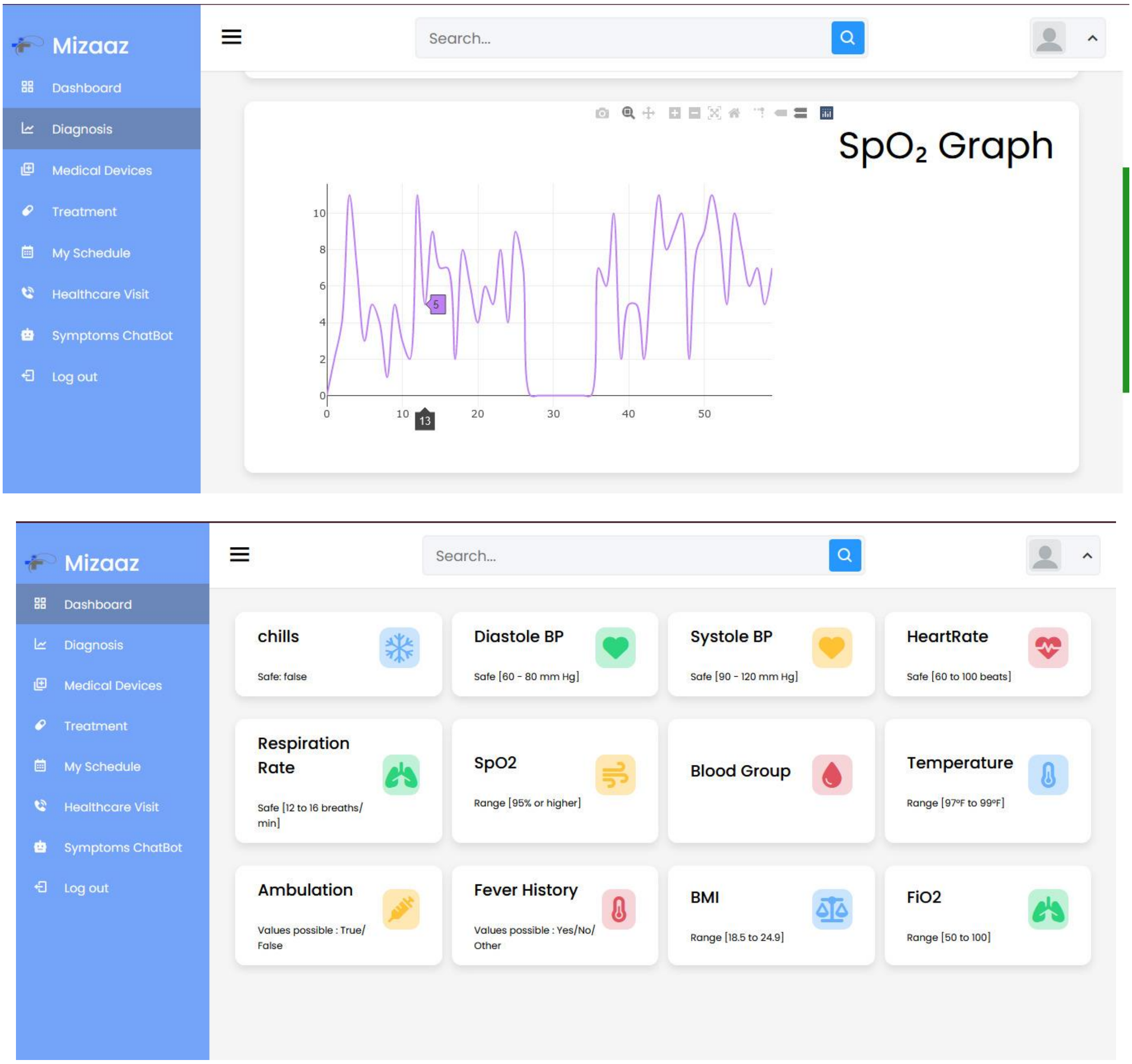


Fig 7: Web based platform visualization

These are summarized as follows:

1. **Patient Login**

The patient dashboard provides comprehensive features to give all vital signs. This data is fetched in real-time and generated by the sensors attached to the patient. The data is represented in an easy-to-understand manner.

Patient Login Features:

- **User Dashboard: R**eal-time parameters like heart rate, blood pressure, and temperature, alongside historical data trends to track health progress over time, are displayed with visualizations.
- **Appointment Booking:** Enable to schedule appointments with doctors. It also enables you to view available time slots and receive appointment reminders.
- **Calendar Schedule: Provide** a personal health calendar as per medical schedules, including medication timings, exercise routines, diet, and follow-up appointments.
- **Local Healthcare Directory:** This is GPS-enabled subsystem integrated with UI. This assists in finding nearby healthcare providers, like doctors, pharmacies, etc.
- **Chatbot for Disease Prediction: It is an** AI-powered chatbot. patients input their symptoms and can get an immediate preliminary assessment, which guides them to seek further appropriate medical advice.
- **Report Downloading:** Patients can download their medical reports and health data for personal records or to share with external healthcare providers.

2. Doctor Login

Doctors' login provides all essential features for efficiently managing all associated patients. This interface supports the review of extensive medical histories.

Doctor Login Features:

- **Patient Health Overview:** Doctors can access detailed health information and vital sign data for each patient, which is critical for diagnosis and treatment planning.
- **Report Generation:** Doctors can generate and send medical reports. Reports can be sent directly to patients and/or their attendants.

● **Emergency Alerts:** Immediate intervention and care can be provided to patients by doctors alerted to patient attendants and health care service providers.
● **Case History Review:** A searchable database is implemented. This allows doctors to review the case histories of different sets of patients, compare health outcomes, and refine treatment plans based on historical data.

3. **Patient Attendant Login**
Patient attendants have separate logins. This focuses on continuous monitoring of their patient's health status. This ensures prompt alerts about any critical changes or emergencies.

Patient Attendant Login Features:
● **Vitals Monitoring:** Attendants can monitor patients' vitals in real-time, gaining insights into their health status.
● **Report Access:** Patient attendants have access to all reports and health documents, which can be crucial for coordinating care, especially in emergency situations.

V. ADVANTAGES

Such IoT-based healthcare systems can be correctly referred to as Telehealth. These are getting endorsements from various governments and agencies. These platforms consist of many sub-systems to facilitate round-the-clock connectivity between patients and physicians. This connectivity becomes feasible with internet connection and IoT technologies. The use of such Telehealth holds significant promise for the present and future enhancement of healthcare services. The proposed system is efficient and ensures high-quality healthcare access for all, consequently minimizing the need for manual labor and having a scalable architecture.

VI. CONCLUSION

The integration of the Internet of Things (IoT) into healthcare enables a transformative shift towards the efforts of providing more accessible, efficient, and effective healthcare delivery to everyone. The proposed system, using wearable sensors, sophisticated data processing algorithms, and wireless communication networks, facilitates immediate medical response. This also helps in the personalized patient care process. Further, the proposed platform helps reduce healthcare professionals' overall workload. The test runs of the proposed system prove its efficiency. With technological advances, the proposed system would see more features and user-friendliness moving towards a more patient-centric approach.

REFERENCES

1. A. I. Siam et al., "Portable and Real-Time IoT-Based Healthcare Monitoring System for Daily Medical Applications," in IEEE Transactions on Computational Social Systems, vol. 10, no. 4, pp. 1629-1641, Aug. 2023.
2. Y. Yang, H. Wang, R. Jiang, X. Guo, J. Cheng and Y. Chen, "A Review of IoT-Enabled Mobile Healthcare: Technologies, Challenges, and Future Trends," in IEEE Internet of Things Journal, vol. 9, no. 12, pp. 9478-9502, 15 June 15, 2022.
3. P. Kamble and A. Birajdar, "IoT Based Portable ECG Monitoring Device for Smart Healthcare," 2019 Fifth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), Chennai, India, 2019, pp. 471-474.
4. T. H. Nguyen, T. T. Le, W. A. Khan, L. Hoang, and T. Q. Duong, "A Hybrid Deep Learning Model for Fall Detection Using Wearable Sensors," *IEEE Journal of Biomedical and Health Informatics, vol. 25*, no. 12, pp. 4869-4881, Dec. 2021.
5. A. S. Rawat, J. P. Singh, and D. P. Agrawal, "Wearable Devices in Healthcare: A Comprehensive Review," *IEEE Internet of Things Journal, vol. 8*, no. 11, pp. 8281-8317, Nov. 2021.
6. S. S. Vedaei et al., "COVID-SAFE: An IoT-Based System for Automated Health Monitoring and Surveillance in Post-Pandemic Life," in *IEEE Access, vol. 8*, pp. 188538-188551, 2020,.
7. P. Gope and T. Hwang, ‘‘BSN-care: A secure IoT-based modern healthcare system using body sensor network,’’ *IEEE Sensors J., vol. 16*, no. 5, pp. 1368–1376, Mar. 2020.
8. P. Verma and S. K. Sood, ‘‘Cloud-centric IoT based disease diagnosis healthcare framework,’’ *J. Parallel Distrib. Comput., vol. 116*, pp. 27–38, Jun. 2018.
9. P. P. Ray, ‘‘Internet of Things based physical activity monitoring (PAMIoT): An architectural framework to monitor human physical activity,’’ in *Proc. IEEE CALCON, Kolkata, India,* Nov. 2020, pp. 32–34
10. [10] Mardini, M.T., Iraqi, Y. & Agoulmine, N. A Survey of Healthcare Monitoring Systems for Chronically Ill Patients and Elderly. *J Med Syst* 43, 50 (2019).
11. W. T. Vambe and K. Sibanda, "A Fog Computing Framework for Quality of Service Optimisation in the Internet of Things (IoT) Ecosystem," 2020 *2nd International Multidisciplinary Information Technology and Engineering Conference (IMITEC), Kimberley, South Africa*, 2020, pp. 1-8.
12. Z. Sun, Z. Lv, H. Wang, Z. Li, F. Jia and C. Lai, "Sensing Cloud Computing in Internet of Things: A Novel Data Scheduling Optimization Algorithm," in *IEEE Access, vol. 8*, pp. 42141-42153, 2020.
13. R. L. Devi and V. Kalaivani, ‘‘Machine learning and IoT-based cardiac arrhythmia diagnosis using statistical and dynamic features of ECG,’’ J. Supercomput., pp. 1–12, May 2019
14. S. Baskar, V. R. S. Dhulipala, P. M. Shakeel, K. P. Sridhar, and R. Kumar, ‘‘Hybrid fuzzy based spearman rank correlation for cranial nerve palsy detection in MIoT environment,’’ Health Technol., vol. 10, no. 1, pp. 259–270, Jan. 2020.
15. J. D. Trigo et al., "Patient Tracking in a Multi-Building, Tunnel-Connected Hospital Complex," in IEEE Sensors Journal, vol. 20, no. 23, pp. 14453-14464, 1 Dec.1, 2020.
16. M. J. Baucas, P. Spachos and S. Gregori, "Internet-of-Things Devices and Assistive Technologies for

Health Care: Applications, Challenges, and Opportunities," *in IEEE Signal Processing Magazine, vol. 38,* no. 4, pp. 65-77, July 2021

17. A. Mdhaffar, T. Chaari, K. Larbi, M. Jmaiel and B. Freisleben, "IoT-based health monitoring via LoRaWAN," IEEE EUROCON 2017 -17th International Conference on Smart Technologies, Ohrid, Macedonia, 2017, pp. 519-524.
18. DHT-11 Digital Temperature And Humidity Sensor, Temperature and Humidity Sensor, Sensor Modules, https://robu.in/product/dht-11-digital-temperature-humidity-sensor/, 2nd March, 2024 16:25 hrs.
19. MAX30100 Pulse Oximeter Interfacing with Arduino, https://www.electronicwings.com/arduino/max30100-pulse-oximeter-interfacing-with-arduino , 2nd March, 2024 16:40 hrs.
20. Interfacing MAX30100 Pulse Oximeter and Heart Rate Sensor with Arduino, https://lastminuteengineers.com/max30100-pulse-oximeter-heart-rate-sensor-arduino-tutorial/, 2nd March, 2024 16:30 hrs
21. Raspberry pi 2 Model B 1GB- The Complete Kit, Motherboards, Components, Computers and Accessories, https://www.amazon.in/Raspberry-Pi-Model-1GB-Complete/dp/B00T2U7R7I , 2nd March 2024.