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Design and Development of an IoT Based Wearable Vital Signs Measuring Smart Device for Diagnosing and Managing Various Health Conditions

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ABSTRACT: The increasing demand for continuous health monitoring and early detection of medical conditions has led to the development of innovative wearable technologies. This paper presents the design and development of an IoT-based wearable smart device capable of measuring vital signs to aid in the diagnosis and management of various health conditions. The device integrates multiple sensors to monitor key physiological parameters, including heart rate, body temperature, and blood oxygen levels (SpO2). These sensors are connected to a microcontroller, which processes the data and transmits it to a cloud-based platform via wireless communication protocols. The system architecture leverages IoT technology to enable real-time data collection, storage, and analysis, making it possible for healthcare providers to remotely monitor patients and make informed decisions. The device is designed to be lightweight, energy-efficient, and comfortable for continuous wear, ensuring usability across different patient demographics. Additionally, the smart device includes features for alerting users and healthcare providers to abnormal readings, thereby facilitating timely interventions. This paper discusses the technical challenges encountered during the development process, such as sensor integration, power management, and ensuring data security and privacy. It also highlights the potential applications of the device in managing chronic diseases, post-operative care, and remote patient monitoring. The prototype's performance is evaluated through a series of tests, demonstrating its reliability and accuracy in measuring vital signs. The study concludes that this IoT-based wearable device has significant potential to enhance healthcare delivery by providing a convenient, efficient, and scalable solution for continuous health monitoring.

KEYWORD: IoT-base, Wearable Smart Device, IoT Sensor, Cloud Integration, Mobile Health Application, Health Data Analytics

1. INTRODUCTION

The growing prevalence of chronic diseases and the increasing demand for personalized healthcare solutions have fueled interest in the development of wearable health monitoring devices. According to the World Health Organization (WHO), chronic diseases such as cardiovascular diseases, diabetes, and respiratory conditions account for approximately 71% of all deaths globally, emphasizing the need for continuous monitoring and timely intervention to manage these conditions effectively (WHO, 2021). Published guidance, 2021 from the American Heart Association (AHA) supports the use of remote patient monitoring for patients with chronicle diseases. The AHA determined that the technologies used for remote patient monitoring contribute to better chronicle disease outcomes and concluded that the RPM is a cost-effective and value-enhancing solution. Traditional healthcare systems, which rely heavily on in-person consultations and periodic check-ups, often fall short in providing the real-time data necessary for early diagnosis and effective management of these health issues.

According to Malasinghe et al, 2019 study, IoT-based health monitoring systems have a number of benefits, including ongoing patient monitoring, real-time illness detection, a reduction in the need for and cost of hospitalization, technology use, emergency medical aid, and lastly, more accurate data collection. Some hospitals have even adopted a service model that requires one to pay a subscription fee.

Wearable technologies are extensively developed by researchers to monitor patients with chronic diseases. Wearable health devices have come a long way from basic pedometers to sophisticated gadgets capable of tracking multiple physiological parameters. Early wearable's focused primarily on tracking physical activities, such as step count and calories burned. These advancements have enabled continuous health monitoring, leading to better disease management and improved patient outcomes. Wearable devices that measure vital signs are particularly beneficial as they provide real-time data, facilitating timely medical interventions.

Over the years, advancements in sensor technology have expanded the capabilities of these devices to include monitoring heart rate, blood pressure, oxygen saturation, body temperature, and other vital signs. Usage of GSM module has become very popular nowadays. It is used to establish connection between a GPRS system and a computer. It could be also done with transceiver which is used for data sending and receiving, (Nwabueze, et al, 2022). High-precision sensors and advanced algorithms can enhance the accuracy of data captured by wearable devices.

These technologies can be demonstrated through wearable armbands or patches embedded in a patient's body. These patches are designed according to the required operation. These wearable patches require a biosensor. Different biosensors, such as an electrocardiogram (ECG), electroencephalogram, blood pressure, and oxygen saturation (SpO_2) sensors, are developed by researchers. However, the effective wireless transmission of these bio-signals has recently attracted a considerable research interest. The bit-error rate (BER) is highly significant in this regard, because the reliability issue must be addressed with proper attention. In real-time remote monitoring of a patient's condition (e.g., the heart rate), the data transmission should be almost completely error-free. There are a few hospitals with modern equipment, but they are expensive for individuals living in remote areas. Moreover, doctors are reluctant to travel to those remote places and provide care for the locals. However, practically every village has access to the Internet. This issue served as inspiration for the system that was proposed, which will help the patients because they may utilize the real-time monitoring system to prevent heart attacks, take their medications on schedule, and consult doctors from home.

2. CONCEPTUAL THEORY

This conceptual framework outlines the design and development of an IoT-based wearable smart device aimed at measuring vital signs and assisting in diagnosing and managing various health conditions, therefore presents the functional concept of the research problem, discussing its possibility of revolutionizing the industry with material/ components used and discussing few challenges and problems with remote observing of patients. Also it presents some of the most common cardiovascular diseases, their symptoms, causes, and treatment options. It also delved into the categories of people who are at an increased risk of developing one or the other form of heart disease.

The theories of this conceptual framework which is based on the interaction of four main components: the wearable device, IoT infrastructure, data analytics, and healthcare outcomes. Each component plays a vital role in the overall functioning of the system.

2.1.1. Wearable Device Component

This component focuses on the design and development of the wearable smart device. The element of this components Includes:

Sensor Integration: The device incorporates multiple sensors to measure vital signs such as heart rate, blood pressure, body temperature, oxygen saturation, and electrocardiogram (ECG) readings. Advanced sensors may also include accelerometers and gyroscopes for detecting falls and monitoring physical activity levels (Pantelopoulos & Bourbakis, 2010).

User Interface: The device must have a user-friendly interface that allows for easy operation by the user. This could involve a small display on the device or integration with a smartphone app (Patel, Park, Bonato, Chan, & Rodgers, 2012).

2.1.2. IoT Infrastructure Component

The IoT infrastructure is responsible for the connectivity and data transfer between the wearable device and the healthcare provider. The element of this components Includes:

Communication Protocols: The device should support multiple communication protocols, such as Bluetooth, Wi-Fi, and cellular networks, to ensure seamless data transmission (Gubbi, Buyya, Marusic, & Palaniswami, 2013).

Cloud Integration: Data collected by the device is transmitted to the cloud for storage and processing. Cloud computing facilitates the analysis of large datasets, enabling real-time monitoring and decision-making (Islam, Kwak, Kabir, Hossain, &Kwak, 2015).

2.1.3. Data Analytics Component

Data analytics play a critical role in interpreting the data collected by the wearable device. The element of this components Includes:

Data Processing and Analysis: The system must process the raw data to generate meaningful insights. Machine learning algorithms can be employed to detect patterns and anomalies in the data, potentially predicting health issues before they become critical (Lobato, Molina, & Bustamante, 2019).

Personalized Health Insights: Based on the analyzed data, personalized health insights and recommendations can be provided to users and healthcare providers. This enhances the ability to manage chronic conditions and improves patient outcomes (Bui &Zorzi, 2011).

2.1.4. Healthcare Outcomes Component

The final component is focused on the impact of the wearable device on healthcare outcomes. The element of this components Includes:

Early Diagnosis and Intervention: Continuous monitoring enables the early detection of potential health issues, allowing for timely intervention and management (Clifford, Clifton, &McSharry, 2012).

Patient Engagement and Empowerment: The device empowers patients by providing them with real-time information about their health, encouraging active participation in their healthcare (Kvedar, Coye, & Everett, 2014).

Improved Healthcare Delivery: Healthcare providers can make more informed decisions based on real-time data, leading to improved care delivery and outcomes (Istepanian, Hu, Philip, & Whittlesey, 2011).

In recent years, a great number of IoT frameworks have been developed for use in IoT applications that are associated with assisted living and medical services, (Dey, et al, 2017). As this system is generally based on wearable smart sensor on the patient's body that collects data remotely and transfers it to the healthcare, its efficiently updates doctor about the health status of the patients and accurately measures the parameters of patient and data (is then accessed remotely by doctor or health care specialists who monitor and may make decision based on the data) been sent to a registered number via GSM, (Babu, ..2018).

The delivery of healthcare services for patients with chronic diseases requires more effective coordination between professionals and patients/relatives along the care pathway. In response, many health care organizations have implemented this kind of Systems. This type of intervention program can improve patient follow-up and have a positive impact on the quality of care (reducing toxic effects, improving treatment compliance, limiting adverse events) and health-related costs (reducing the duplication of prescriptions and hospital readmissions).,(Marie et al..,2020).

2.2: CARDIOVASCULAR DISEASE

Cardiovascular disease (CVD) is general term for conditions affecting the heart and blood vessels, usually connected with a development of fatty deposits inside the arteries (atherosclerosis) and an increased risk of blood clots, including conditions such as coronary artery disease, heart failure, stroke, and peripheral artery disease. It can likewise be related with damage to arteries in organs such brain, heart, kidneys and eyes. In recent decades, cardiovascular disease has supplanted all other causes of mortality to become the leading cause of death in the United States. It is quite challenging for medical professionals to make a correct diagnosis in a timely manner, (Kumar et al 2019). Because of this, the incorporation of computer expertise into this study is essential if it is to aid healthcare practitioners in providing timely and correct diagnoses.

In 2015 alone, according to www.tourmyindia.com, more than 17 million people died globally because of heart disease. It accounts for 31 percent of all the deaths in the year. Out of 17 million, more than 7 million people die because of just two types of cardiovascular disease – coronary artery disease (CAD) and stroke.

Before these last few decades, heart disease was mostly seen as an issue that only older people faced. These days, however, it is well-acknowledged that it is one of the leading causes of mortality for individuals of all ages. It has been shown that India has a heart disease prevalence rate that is two times higher than the average for the rest of the world. In spite of the fact that heart disease is becoming more prevalent, a significant number of Indians continue to be ignorant of the symptoms that may accompany it. Even though having a history of heart disease in one's family is a significant risk factor in and of itself, the majority of heart-related disorders are caused by factors, such as high blood sugar, high cholesterol, high blood pressure, an unhealthy diet, smoking, a sedentary lifestyle, stress, and obesity. At this point in time, an individual's manner of life is the single most important factor in determining whether or not they will acquire heart disease, (Pradhan,, et al 2021) .

According to clevelandclinic.org, cardiovascular disease symptoms can vary depending on the cause. It affects people of all ages, sexes, ethnicities and socioeconomic levels and a person may be symptomatic (physically experiencing the disease) or asymptomatic (not feeling anything at all). The sooner you detect cardiovascular disease, the easier it is to treat. Without appropriate treatment, heart disease can lead to heart attacks or strokes. Heart attacks and strokes are usually acute events and are mainly caused by blockage that prevents blood from flowing to the heart or brain. Some of this heart disease associated with atherosclerosis, which is a condition that develops when a substance called plaque builds up in the walls of the arteries. This buildup narrows the arteries, making it harder for blood to flow through. If a blood clot forms, it can block the blood flow. This can cause heart attack or stroke. Figure 1 shows blocked arteries.

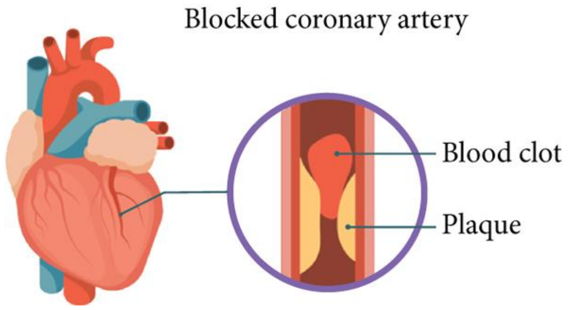

FIGURE 1: BLOCKED ARTERIES IN A HUMAN HEART

When it comes to recognizing a stroke, the acronym **BE FAST** is used by the American Stroke Association. This acronym stands for the main symptoms associated with early signs of a stroke, such as:

- **B:** Be watchful for a sudden loss of balance
- **E:** Looking out for sudden loss of vision in one or both eyes. Are they experiencing double vision?
- **F:** facial drooping on one side of the face:. Ask the person to smile. Look for a droop on one or both sides of their face, which is a sign of muscle weakness or paralysis.
- **A**: arm weakness: A person having a stroke often has muscle weakness on one side. Ask them to raise their arms. If they have one-sided weakness (and didn't have it before), one arm will stay higher while the other will sag and drop downward.
- **S**: slurred speech or speech difficulty: strokes often cause a person to lose their ability to speak. They might slur their speech or have trouble choosing the right words.
- **T**: time to call emergency services: Time is critical, so don't wait to get help! If possible, look at your watch or a clock and remember when symptoms start. Telling a healthcare provider when symptoms started can help the provider know what treatment options are best for you.

According to Dr. Rabih Kashouty of premierneurologycenter.com, in addition to the classic stroke symptoms associated with the **BE FAST** acronym, around 7-65% of people undergoing a stroke will experience some form of a headache. People describe a stroke-related headache as a very severe headache that comes on within seconds or minutes. Oftentimes, the area affected by the headache is directly related to where the stroke occurs. For example, a blocked carotid artery can cause a headache on the forehead, while a blockage towards the back of the brain can cause a headache towards the back of the head. This ultimately means that there is not one headache location that signals a stroke, since they can occur anywhere on the head.

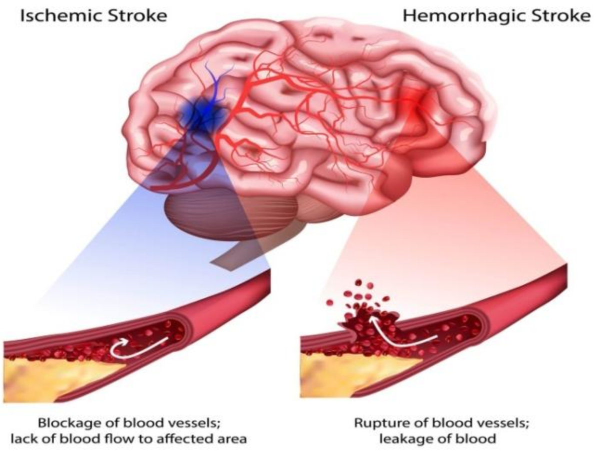

FIGURE 2: BRAIN STROKE

2.2.1. Challenges in developing IoT Based wearable Devices

While the potential of IoT-based wearable devices in healthcare is significant, several challenges need to be addressed to ensure their widespread adoption and effectiveness.

- **Design and User Adoption:**

One of the critical challenges in developing wearable devices is ensuring user adoption. Davis introduced the Technology Acceptance Model (TAM), which suggests that perceived usefulness and ease of use are key determinants of user acceptance. Venkatesh and Davis (2000) further extended this model, emphasizing that user-friendly design and clear benefits are crucial for encouraging the adoption of wearable health devices.

- **Battery Life and Device Maintenance:**

Wearable devices require efficient power management to ensure continuous operation. Patel et al. (2012) noted that battery life is a major constraint in the design of wearable devices, as continuous monitoring and data transmission can be power-intensive. Innovative energy-harvesting technologies and low-power sensors are being explored to address this issue.

- **Interoperability and Standards:**

Ensuring that wearable devices can communicate with other healthcare systems is essential for seamless data integration. Istepanian et al. (2011) discussed the need for standardization in IoT-based health systems to ensure interoperability across different platforms and devices. This would enable the integration of wearable device data into electronic health records (EHRs), enhancing the overall efficiency of healthcare systems.

3.0. METHODOLOGY

The design and development of an IoT-based wearable smart device for measuring vital signs involves the integration of hardware (sensors), software (data processing algorithms), and communication technologies (IoT) to provide continuous health monitoring and diagnostics. The goal of the device is to collect real-time physiological data, transmit it to a centralized platform for analysis, and provide insights for managing various health conditions.

The first step involves determining the specific health conditions that the device will be designed to monitor and manage. Common health conditions that benefit from continuous monitoring include cardiovascular diseases, respiratory conditions, diabetes, and stress-related disorders. The vital signs to be measured typically include:

- Heart rate
- Blood pressure
- Blood oxygen level (SpO2)
- Body temperature

This methodology provides a comprehensive approach to design and developing an IoT based wearable vital signs measuring smart device for diagnosing and managing various health condition. A proper understudy of the records and process of remote monitoring system was carried out through Research, data gathering from various sources, such as interviewing and personal discussion with Medical Personnel at hospital.

The method used to achieve this improved Remote monitoring system for patients are;

Firstly, the remote monitoring system was characterized in order to pinpoint the weakness of the existing system below.

This existing system presents an internet-based tele-monitoring system, which has been developed as an instance of the general client-server architecture presented in Figure 3.1**.**

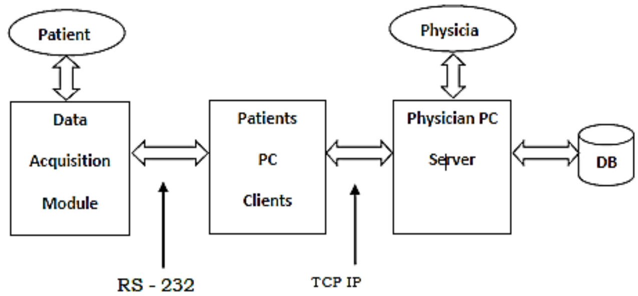

FIGURE 3.1: GENERAL DIAGRAM OF AN INTERNET-BASED TELE-MEDICAL SYSTEM

The data acquisition subsystem was designed taking into consideration the requirements of a nonclinical situation. The DAM was implemented as a battery operated device. The removes of unwanted frequencies in this case requires three filters. A low-pass filter is implemented cascaded the signals from the gain amplifier with frequency higher than 100Hz A notch filter or band reject filter is used to reduce 60 Hz noise. A 60 Hz notch filter circuit was implemented using TL082 IC.

Finally, a high-pass filter is used to allow the signal that has frequency above 10Hz. It should be noted that a band-pass filter was not used because the pass-band was large, and it is recommended cascaded high-pass, low-pass filters be used in this case. The digital section comprises the data conversion section and the control unit. A/D converter was employed.

3.1. Proposed System Design

The main objective is to design a Patient Monitoring System with two-way communication i.e. not only the patient's data will be sent to the doctor on emergencies, but also the doctor can send required suggestions to the patient or guardians through SMS or Call or Emails.

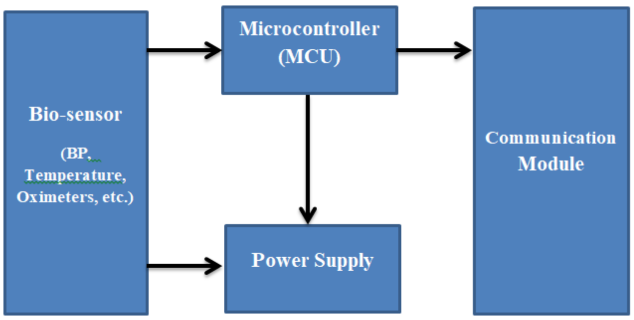

FIGURE 3.2: BLOCK DIAGRAM OF PROPOSED SYSTEM

3.2. System Description and Design: Architecture

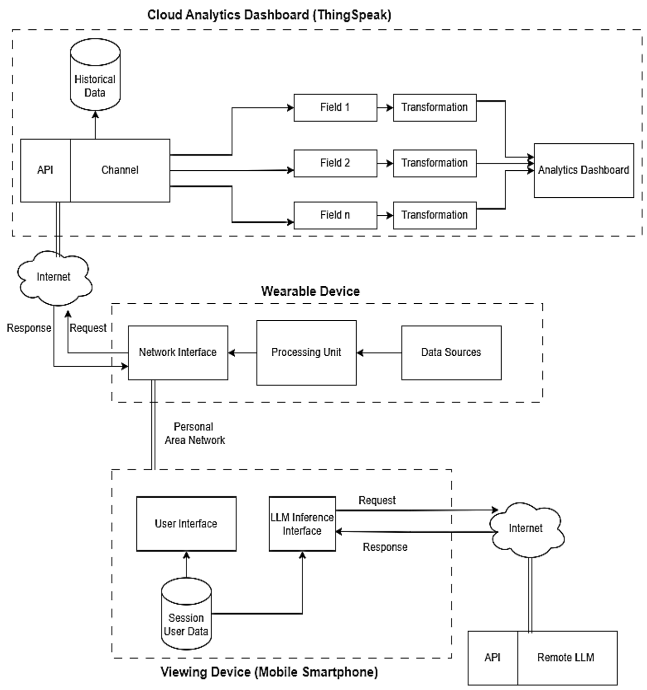

FIGURE 3.3: ARCHITECTURE OF THE SMART MONITORING WEARABLE

The implementation is structured around three main structures: the wearable device, a viewing device, and an analytics dashboard.

3.2.1. Wearable Device

The wearable device contains three subsystems: data acquisition, processing unit, and radio interface. The data acquisition block consists of the sensors that retrieve the health metrics and circuits built around these sensors. The processing unit is the onboard processor. It conditions the acquired metrics, constructs a payload, and transmits it over a communication link. The processing unit orchestrates all incoming and upcoming dataflows between the wearable and other external systems.

The wearable interfaces with the analytics dashboard are via HTTP, calling a read or write ThingSpeak application programming interface (API). The viewing device's interface is established over a personal area network, specifically Bluetooth.

3.2.2. Viewing Device

The viewing device is used alongside the wearable to observe the metric it acquires in real time. This part of the system can be considered an extension of the wearable, as the functionality is limited without it. It is implemented using a mobile smartphone running a custom application for the wearable.

The viewing device has two functions. First, it stores and renders the data the wearable senses in real-time on a user interface. The data stored is the average of the health metrics over the lifetime of the current session. A session in this context begins when the wearable and viewing device are paired and ends when the connection is torn down. The second function is interfacing with an external language model (large language model or LLM). It provides functionality for users to ask for health tips, taking into consideration their stored metrics.

3.2.3. Analytics Dashboard

The cloud platform used is ThingSpeak. ThingSpeak organizes data streams into channels and fields. Each channel is made up of several fields. In the block diagram in FIG. 3.4, the channel acts as a demultiplexer. When a payload is received in a channel, it is further examined and routed to the appropriate field. REACT mechanisms are used to trigger code scripts that transform the data, after which it is sent to a dashboard.

The setup on the cloud also stores data in the long term. Note the difference between the storage functionality on the edge device (smartphone) and the cloud. The database on the cloud stores each data point received for an extended period to support historical analysis, while the database on the edge stores averages, continuously updated throughout a session's lifetime and discarded when the session ends.

3.2.4. Data flow Diagram

A data flow diagram (DFD) visually represents how data moves through an information system. It focuses on the flow and transformation of data from input to output. It shows the processes that manipulate the data, the data stores where information is held, and the external entities interacting with the system. DFDs are particularly useful for understanding the logical flow of information and how data is processed at various stages within a system.

While an architecture diagram gives a broad understanding of system components and their interactions, a dataflow diagram complements this by providing insight into the flow and processing of information within and between these components. This dataflow diagram is in FIG. 3.4 represents the system. The wearable device contains sensors that capture various medical metrics from the user. These sensors collect raw data, which is then processed by the wearable device itself.

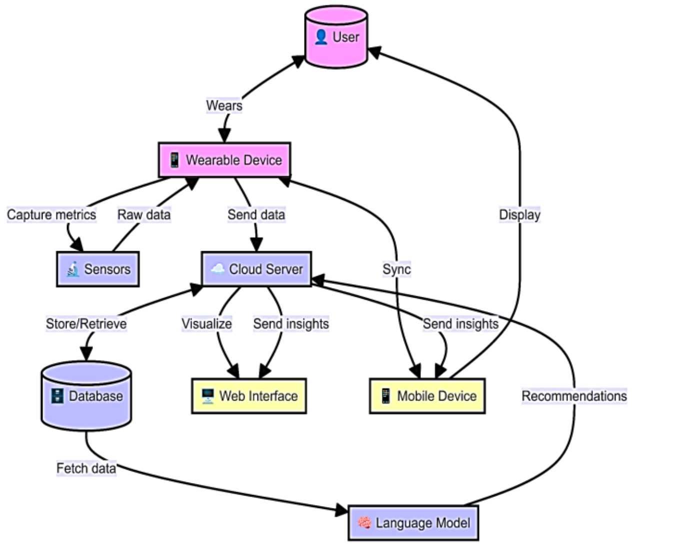

FIGURE 3.4: DATA FLOW DIAGRAM OF THE SYSTEM.

Data coming from the wearable takes two paths, as shown in Figure. 3.4. First, it's sent to a cloud server. This server is the central data storage, processing, and analysis hub. The cloud server stores the incoming data in a database, preserving historical information for trend analysis and future reference. The cloud server also handles data visualization, likely through a web interface. This allows users or healthcare providers to access detailed visualizations of the medical metrics through a web browser, providing a comprehensive view of the data over time. The second path the data takes is to the user's mobile device. This direct connection is via a wireless interface such as Bluetooth, allowing users to view real-time data on their smart devices. This immediate access to information empowers users to stay informed about their health metrics throughout the day. An innovative aspect of this system is its integration with a language model. The stored data in the local database is sent to this model on-demand, which analyzes trends in the medical metrics. Based on these trends, the language model generates personalized recommendations or insights. These AI-generated recommendations are then sent back to the edge device and rendered on their display.

4. RESULTS

The results are seen in the patient's user interface which is designed for simplicity and ease of use, ensuring that users of all ages and technical skill levels can interact with it. The dashboard features include:

- **Real-time Health Dashboard**: Displays current vital signs (heart rate, blood pressure, blood oxygen level, etc.) and highlights any abnormal readings with alerts.

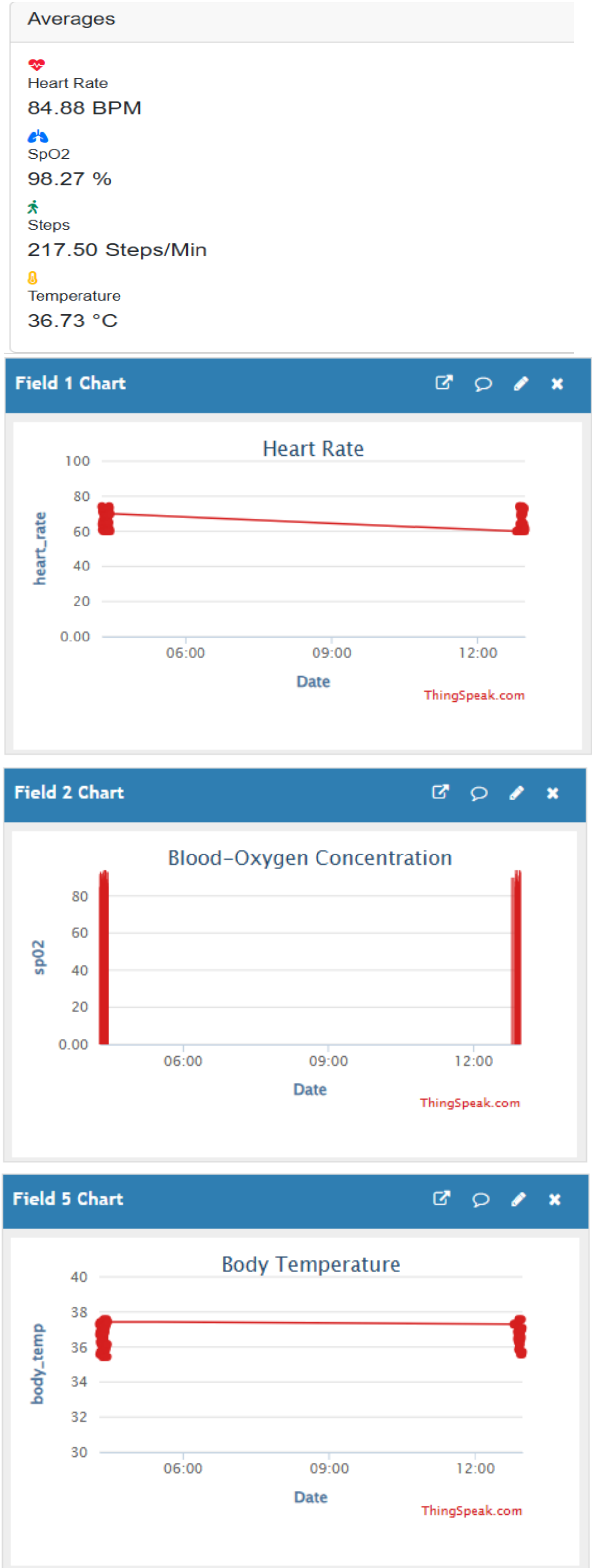

FIGURE 4.1: REAL-TIME HEALTH DASHBOARD

- **AI-Driven Suggestions**: Provides personalized health tips, such as dietary suggestions, exercise routines, or medication reminders based on the patient's data. The sensor data is rendered in real-time on the first screen.

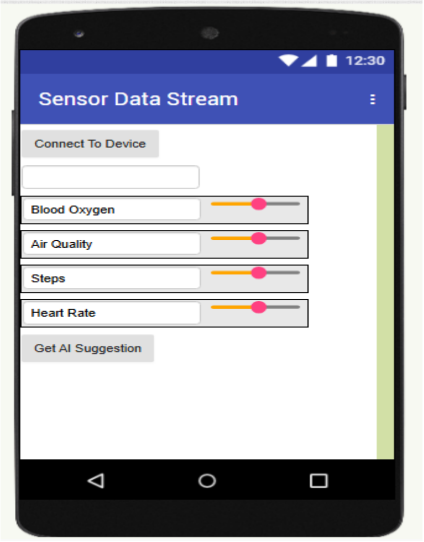

FIGURE 4.2: HEALTH METRICS FROM THE WEARABLE ARE REPORTED IN REAL-TIME ON THE “SENSOR DATA STREAM” SCREEN.

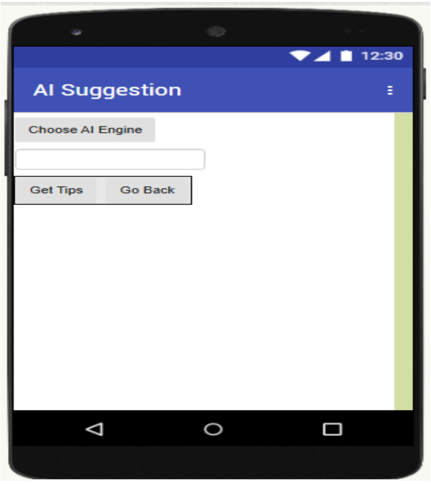

FIGURE 4.3: AI SUGGESTION USER INTERFACE TESTING TECHNIQUE:

To evaluate the performance of the AI suggestion component, we conducted a series of tests using our mock setup. The setup is a modified interface with the original data stream temporarily removed and replaced with user-settable sliders, as shown in Figure 4.3.

Three user profiles are defined to test the system's versatility:

1. Sedentary User Profile: Low physical activity, normal vital signs
2. Highly Active User Profile: High physical activity, slightly elevated body temperature
3. Unusual Metric Combination: Elevated heart rate and body temperature, moderate activity

A hundred mock health metric data samples were generated, covering all the profiles and including some edge cases with unusual metric combinations. Each data set was processed through the suggestion pipeline, and the results were analyzed for relevance, consistency, and potential impact on user health behaviors.

TABLE 3: SUMMARIZES THE KEY PERFORMANCE METRICS OF THE AI SUGGESTION SYSTEM:

Metric	Value
Average response time	1.2s
Suggestion relevance score (1-5 scale)	4.3
Unique suggestion rate	78%
Edge case handling success rate	92%
User comprehension score (1-5 scale)	4.7

- Average response time measures the time taken from when the user requests a suggestion to when the AI-generated advice is displayed on their screen.
- The suggestion relevance score is determined by assigning a numerical value on a 1 -5 scale to how well the AI's suggestions align with the given health metrics.
- The unique suggestion rate percentage represents how often the system provides distinct suggestions for the same user over time. A high rate of unique suggestions helps maintain user engagement by offering varied advice and preventing repetition.
- Edge case handling success rate assesses the system's ability to provide appropriate suggestions for unusual combinations of health metrics.
- The user comprehension score is a user-reported score that indicates how easily they can understand and act upon the AI's suggestions.

5. CONCLUSION

The Novel idea behind the developing of this smart device for the remote monitoring of vital signs, diagnosing and managing various health conditions is to Provides quality service to one and all. From an engineering perspective, the project has seen concepts acquired through the electrical engineering study period being practically applied

Furthermore, the design and development of an IoT-based wearable device for measuring vital signs have shown great potential to revolutionize the diagnosis and management of various health conditions. This research has demonstrated how the integration of IoT technology with wearable devices can facilitate continuous monitoring of vital signs, providing real-time data that is crucial for early diagnosis, timely intervention, and effective management of chronic diseases.

By leveraging IoT infrastructure, wearable devices can seamlessly collect and transmit health data, enabling healthcare providers to monitor patients remotely. This real-time data exchange is critical for managing chronic conditions and improving patient outcomes. The incorporation of machine learning and data analytics into these devices enhances their ability to predict potential health issues. This shift towards predictive and preventive healthcare is a significant advancement, allowing for early intervention and reducing the risk of severe complications. The success of wearable health devices largely depends on their design and user-friendliness. The research emphasizes the importance of user-centered design, ensuring that devices are easy to use, beneficial, and thus more likely to be adopted by patients and healthcare providers alike.

Finally, this IoT-based wearable device empowers patients by providing continuous monitoring and real-time feedback, which is particularly beneficial for managing chronic diseases. These devices enable a proactive approach to healthcare, improving patient engagement and outcomes.

5.1. Contribution to Knowledge

This research work provides detailed information on assessed Hospital activities and where improvements can be made. In addition, the design and development of an IoT-based wearable device for measuring vital signs and managing various health conditions contribute significantly to the field of healthcare technology in several ways which include:

i. This research advances the application of IoT in healthcare by demonstrating how real-time monitoring of vital signs can be effectively integrated with IoT infrastructure. This integration allows for continuous, remote health monitoring, which is crucial for managing chronic diseases and improving patient outcomes. It highlights the potential for IoT to enable more responsive and personalized healthcare solutions.

ii. By incorporating machine learning algorithms into the data analysis process, this research contributes to the development of predictive healthcare models. These models can analyze patterns in the data collected by wearable devices to predict potential health issues before they become critical. This shift from reactive to proactive healthcare represents a significant contribution to the field, offering new ways to prevent the onset of diseases or complications through early intervention.

iii. The research underscores the role of IoT-based wearable devices in chronic disease management. By providing continuous monitoring and real-time feedback, these devices empower patients to take a more active role in managing their health. This contribution is particularly important for patients with conditions like diabetes, hypertension, and cardiovascular diseases, where ongoing monitoring can lead to better management and outcomes.

5.1. RECOMMENDATION

i. Future work should focus on developing and integrating multiple sensors within a single device to enhance the comprehensiveness of health monitoring. Research should explore the combination of various sensors to provide a more holistic view of a patient's health.

ii. To ensure widespread adoption, future work should focus on making these devices more affordable and accessible. Research into cost-effective materials and manufacturing processes will be crucial in achieving this goal.

iii. Integrating multiple sensors within a single device could enhance the comprehensiveness of health monitoring. Research should explore the combination of various sensors to provide a more holistic view of a patient's health.

By addressing these areas, future research and development efforts can significantly advance the field of IoT-based wearable health devices, ultimately leading to more effective, secure, and user-friendly solutions for diagnosing and managing various health conditions.

ACKNOWLEDGMENT

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Lastly, we acknowledge the support of my family and friends, whose patience and encouragement have been a source of motivation during the course of this research.

To all who contributed directly or indirectly to this work, I am saying a heartfelt thank you. This accomplishment would not have been possible without your support and contributions.

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