Mobile Heart Sync: An IoT Based Portable ECG Monitor

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The healthcare sector has made significant strides with IoT technology, yet a concerning increase in sudden cardiac arrest cases persists, especially in developing nations with limited access to advanced medical devices. This research aims to provide a cost-effective, IoT-integrated solution to address gaps observed in existing cardiac emergency response systems. The Heart Monitoring System captures essential physiological parameters such as BPM, ECG, and SpO2 through accessible sensors, seamlessly relaying data to a smartphone app for comprehensive cardiac health monitoring. Managed by a Raspberry Pi3b+, the system successfully transmits real-time heart vitals to the app. Additionally, it features an advanced emergency alarm triggered during critical situations, enhancing responsiveness and ensuring prompt notifications. The study identifies limitations and proposes areas for improvement, laying the foundation for a portable, affordable, and innovative cardiac health monitoring system committed to user safety.

Keywords: Saturation of Peripheral Oxygen (SpO2), Electrocardiogram (ECG), Beats Per Minute (BPM), Raspberry Pi 3b+, Blynk IoT.

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1. Introduction

The heart, a vital organ, serves as a central pump, circulating oxygen and blood to sustain overall well-being. A heartbeat involves a two-part pumping action, lasting about a second, initiated when blood accumulates in the upper chambers. The SA node generates an electrical signal, causing atrial contraction, propelling blood through valves and marking the diastolic phase. The next phase begins as ventricles fill with blood, and signals from the SA node reach them, initiating contraction. Cardiovascular diseases, causing about one million deaths annually, highlight the importance of monitoring heart rate for researching heart performance and maintaining cardiovascular health.

This paper introduces a heart monitoring system employing IoT. The treatment of many heart- related conditions demands continuous and prolonged monitoring. IoT proves highly beneficial in this regard, replacing conventional monitoring systems with a more efficient scheme. It facilitates the provision of crucial information about the patient's condition, which is readily accessible to the doctor. Furthermore, the real-time monitoring system allows nurses or the attending doctor in the hospital to track the patient's heart rate through the serial monitor.

2. Literature Review

Table 1. Summary of Recent Advances in IoT and ECG Monitoring Research

Ref. No.	Authors	Year	Key Focus/ Area	Methodology	Key Challenges Addressed	Study Limitations	Future Research Directions
[1]	Rami Hodrob et al.	2020	IoT System for ECG Monitoring	IoT with Healthy-pi HAT, Raspberry Pi, cloud-based analysis, Android and web apps	Real-time ECG Monitoring and emergency alerts	Reliance on Internet connectivity	Expansion to another vital sign monitoring
[2]	Ahmad Farhan Ghifari et al.	2020	Minimum System design of the IoT based ECG monitoring	Bluetooth-based ECG monitoring With Atmega328P and AD8232, smartphone connectivity	Cost-effective ECG monitoring without internet	Limited to 100 meters radius	Increasing the range of Bluetooth monitoring
[3]	Hari Kiran Pendurthi et al.	2021	Pulse Sensor and Heartbeat Monitoring	Arduino-based pulse monitor, Bolt Cloud to AWS	Non-invasive, Continuous heartbeat monitoring	Dependent on cloud services	Connects seamlessly with wider healthcare ecosystem
[4]	Mst. Sumaya Akter et al.	2020	Real-time ECG Monitoring	AD8232 sensor, Arduino Nano, NodeMCU, MATLAB GUI	Continuous ECG monitoring, noise management	Limited to specific hardware setups	Integration with broader healthcare systems
[5]	Md. Raseduzza Man Ruman et al.	2020	IoT-based Patient Monitoring	WIFI module, IoT Cloud platform	Real-time vital sign monitoring	Data privacy concerns	Enhanced Data analysis capabilities
[6]	Aanshi	2019	Heart	ML algorithms,	Accurate heart	Algorithm-	Improving

	Gupta et al.		Disease Prediction	sensor data collection	disease prediction	Specific limitations	algorithm efficiency and accuracy
[7]	SM Ahsanuzzaman et al.	2020	Arrhythmia Prediction	Deep learning models, Raspberry Pi,	Predicting arrhythmia with high accuracy	Hardware cost	Extending prediction models to other heart conditions
[8]	E. Konguvel et al.	2022	Affordable ECG Monitoring System	Sensors, microcontroller	Cost-effective cardia monitoring	Scalability	Improving accessibility
[9]	Alvee Rahman et al.	2019	Intelligent Patient Monitoring	ECG sensor, Raspberry Pi, IoT cloud	Automated health assessment	Dependence on continuous power supply	Incorporating AI for advanced data
[10]	T. M. Amir-Ul-Haque Bhuiyan et al.	2023	IoT-based Patient Monitoring	ECG sensor, microcontroller, wireless module	Comprehensive patient monitoring	Limited sensor range	interpretation Enhancing Sensor accuracy and Versatility
[11]	Noorhayati Mohamed Noor et al.	2022	IoT-based Heart Monitoring	8266 NodeMCU, Blynk platform, I-Heart web application	Home-based heart rate and oxygen level monitoring	Connectivity requirements	Expanding to more comprehensive health monitoring
[12]	Nethra et al.	2022	IoT-based ECG Monitoring	ESP32 Wi-Fi module, cloud-based web applications	Accessible ECG monitoring	Data security	Integration with existing healthcare systems
[13]	Fidela Bernadus et al.	2019	Elderly Health Monitoring	Wearable devices, servers, databases, mobile app	Fall detection and heart rate monitoring	Device wearability	Enhancing detection algorithms
[14]	Charushila Patil and Anita Chaware	2021	Wireless Heart Monitoring System	Sensors and resonance frequency, remote Monitoring	Reducing heart attack risks	Battery life	Expanding monitoring capabilities
[15]	Mohd Aqib et al.	2022	IoT-based ECG Measurement	AD8232 ECG sensor, Node MCU ESP8266 Wi-Fi module, Blynk 2.0 platform	Accurate and Prolonged ECG monitoring	Sensor accuracy	Real-time Data analysis and emergency response systems

3. Proposed Design

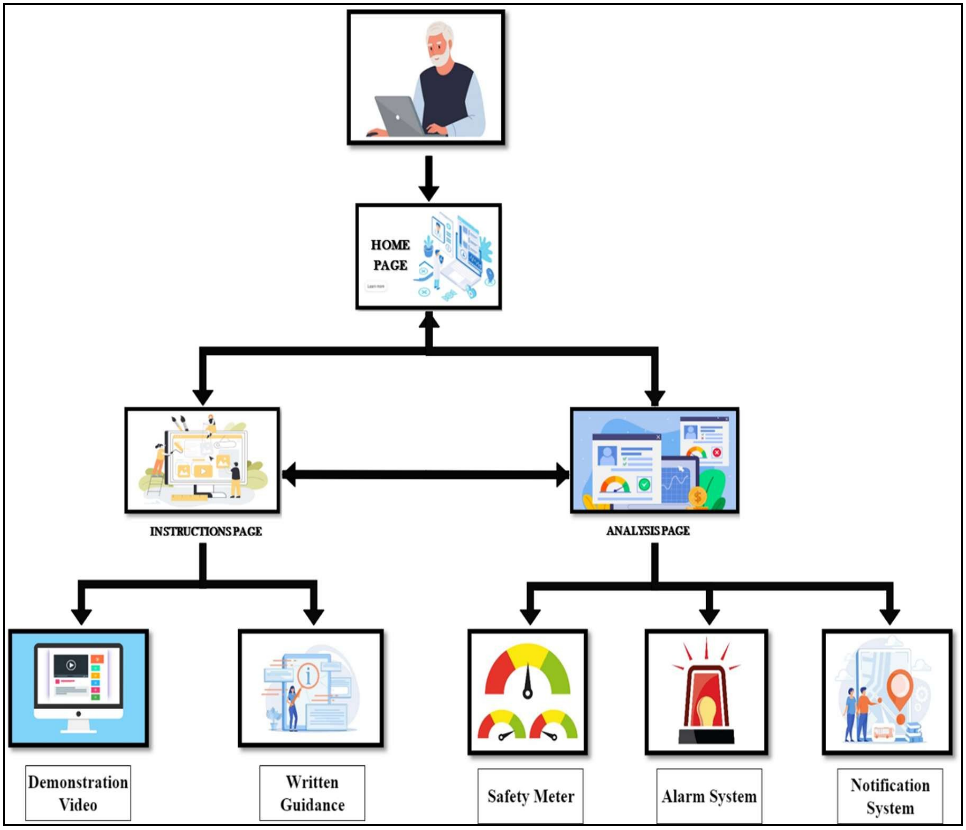

Figure 1. Proposed Design

The Figure 1. Proposed Design, provides a visual guide for users to navigate through the key sections of a website, namely the home, analysis, and instructions pages. The illustration underscores the seamless connectivity between these pages, emphasizing their interrelated nature. Specifically, the instructions page is highlighted, showcasing its comprehensive content that combines a demonstration video with written guidance on utilizing both the portable ECG device and the website effectively. This section serves as a valuable resource for users seeking clear instructions and support. The analysis page is also depicted in the image, featuring crucial elements designed to enhance user experience. Notably, a safety meter for health levels is presented, offering users a visual indicator of their well-being. Additionally, an emergency alarm system is showcased, designed to trigger ambulance dispatch and notify family members during critical situations. This feature underscores the website's commitment to user safety, providing a robust system to address emergency scenarios promptly. Overall, the image communicates the website's user-friendly interface, comprehensive instructions, and advanced analysis tools, all aimed at delivering a seamless and secure experience for users utilizing the portable ECG device.

4. Methodology

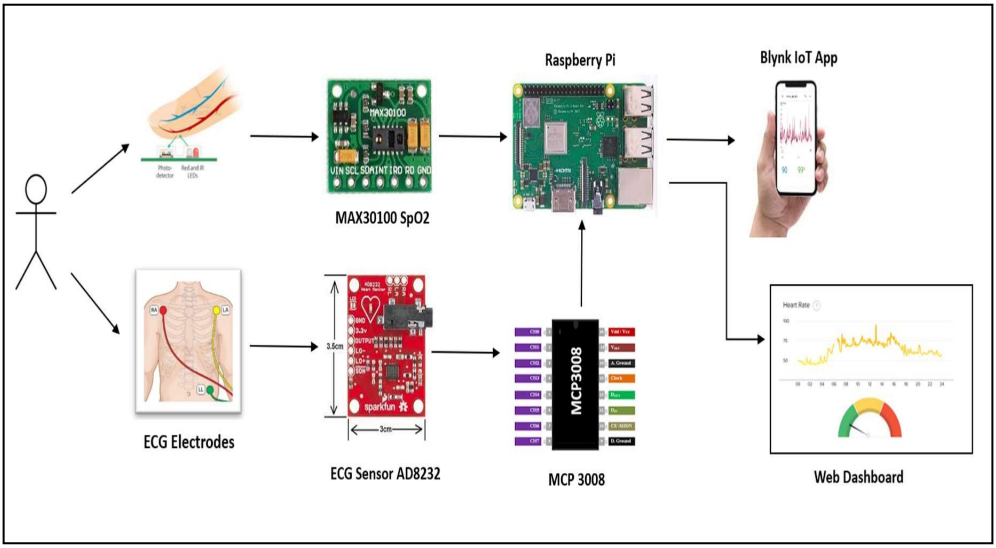

Figure 2. System Architecture

The Figure 2. System Architecture intricately outlines the sophisticated methodology for our cutting-edge heart monitoring system. Commencing with meticulous electrode placement on distinct body points specifically, the left arm, right arm, and lower left, as illustrated users establish connections as indicated in the accompanying diagram. The AD8232 ECG sensor serves as a pivotal component, adeptly capturing analog signals representing the heart's electrical activity. These analog signals undergo a sophisticated processing journey through the MCP3008 analog-to-digital converter, which translates them into a digital format compatible with the subsequent processing unit, namely the Raspberry Pi. Concurrently, the MAX30100 SpO2 sensor enriches the dataset by meticulously measuring blood oxygen levels in percentage and heart rate in beats per minute (bpm). This supplementary sensor significantly elevates the system's capacity to deliver a thorough assessment of the user's cardiovascular health. The Raspberry Pi, serving as the central processing unit, adeptly receives digital signals from the MCP3008. Its primary function involves processing this digital data, undertaking complex calculations for vital parameters such as heart rate and other ECG-related metrics. The seamlessly displayed output data, facilitated by the Blynk IoT platform, ensures users immediate access to crucial health metrics, including an ECG graph, blood oxygen levels, and heart rate. Additionally, a meticulously crafted dedicated website provides users with an interface for real-time monitoring, data analysis, and result visualization. This comprehensive and integrated setup offers a holistic solution for heart rate monitoring and analysis, seamlessly combining cutting-edge hardware components and sophisticated digital processing capabilities to deliver invaluable insights into heart health. In summary, our devised methodology harmoniously unites electrode placement, ECG and SpO2 sensor data acquisition, analog-to-digital conversion, Raspberry Pi processing, and results presentation through the Blynk IoT platform and a dedicated website. The overarching objective of this approach is to furnish a comprehensive, technologically advanced, and user-friendly solution for precise and instantaneous heart health monitoring and analysis.

5. Experimental Work

The Figure 3. Illustrates the working of Pulse oximeter, where the MAX30100 sensor measures blood oxygen levels and pulse rates by emitting light onto the patient's finger and analyzing the absorbed light. Using the I2C protocol, the sensor communicates with the Raspberry Pi 3b+, and the sensor data undergoes processing, as shown in Figure 4. System Implementation. ECG data validation occurs through the LO- and LO+ pins, while the MAX30100 implementation includes averaging values and applying a maximum threshold to handle outliers. To address the lack of a data buffer in the AD8232 sensor, multithreading was implemented on the Raspberry Pi. Three threads were created for reading the AD8232 sensor, reading the MAX30100 sensor, and managing other tasks, ensuring data integrity across threads.

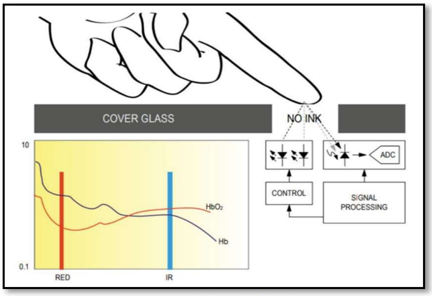

Figure 3. Pulse Oximeter

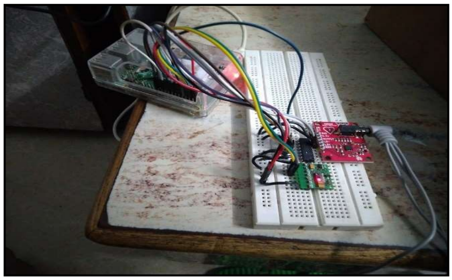

Figure 4. System Implementation

The consolidated data is transmitted to the Blynk Cloud through the provided API, allowing visualization on devices via the Blynk app or web dashboard. The multithreaded system significantly improves throughput, accommodating the faster data transfer rates of the sensors compared to the relatively slower upload speed. Code rewriting for multithreading enhances system consistency.

6. Hardware and Software Details

The system's hardware includes the AD8232 ECG Sensor for recording ECG signals, the MAX30100 Pulse Oximeter for measuring blood oxygen saturation, and the Raspberry Pi 3b+ as the core processor. The MCP3008 enhances data precision, and ECG Electrodes ensure accurate signal capture. On the software side, Raspberry Pi OS supports ECG data collection, and the Blynk IoT App provides a mobile interface for real-time monitoring. Python 3.7 facilitates communication between the ECG sensor and the Blynk platform, creating a robust system for patient-centric physiological monitoring.

7. Result Analysis

Within our health monitoring system, we've meticulously defined specific zones to empower users in interpreting their vital signs. The heart rate's normal range spans between 60 and 100 beats per minute (bpm), with a threshold zone from 50 to 59 bpm and a critical zone below 50 bpm. Similarly, for blood oxygen saturation (SpO2), the normal range is 95% to 100%, the threshold zone is 90% to 94%, and the critical zone falls below 90%. Analyzing the results from the monitoring system, as illustrated in Fig. 4, the recorded heart rate of 90 bpm and SpO2 level of 99% comfortably reside within the normal zones. The website's meter, serving as a reflection of the user's health status, positions the pointer in the green zone, signifying that both heart rate and blood oxygen levels are well within the healthy range. No immediate cause for concern is indicated, portraying the user's cardiovascular health as optimal

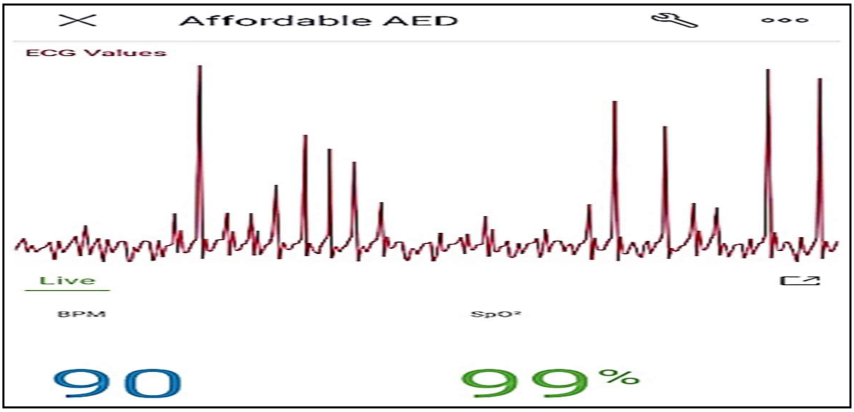

Figure 4. System Implementation

The color-coded zones on the meter enhance clarity, with the green zone reassuring users of normal health, the yellow (threshold) zone suggesting caution and a need for further attention, and the red (critical) zone signaling a potentially serious health issue requiring immediate emergency services and professional intervention. This comprehensive health monitoring system, enriched with visual cues and real-time insights, empowers users to proactively and confidently manage their cardiovascular health. Table 2 provides a quick assessment of your heart risk based on key factors like age, medical history, family history, lifestyle choices, and current health readings. Each parameter is categorized into three risk levels: Green (<20%), Yellow (20-50%), and Red (>50%), helping you understand your overall heart health picture.

Table 2. Heart Risk Stratification Based on Clinical and Lifestyle Factors

Risk Category	Parameter	Green (<20% Risk)	Yellow (20-50% Risk)	Red (>50% Risk)
Health Readings	SpO2	95-100%	90-95%	Below 90%
	Heart Rate	60-100	101-120	>90 or <60
	ECG Graph Readings	Normal	Possible abnormalities	Confirmed abnormalities
Age	Age	20-39 years old	40-59 years old	> 60 years old
Medical History	Diabetes	Non-Diabetic	Pre-Diabetic	Diabetic
	Blood Pressure	Optimal	High-normal	Stage 1 or 2 Hypertension
	Cholesterol	Normal	Borderline	High
Family History	Heart issues in family	No major heart issues in family	1st Degree + Heart Disease	Multiple/Early Onset
Lifestyle and Behavior	Stress Level	Low stress	Moderate stress	High stress or chronic stress
	Smoking and Alcohol Habits	Non-smoker/Moderate	Past/Occasional/ Excessive	Current/Heavy
	BMI	<25	25-29.9	>30
Symptoms	Breathlessness	Absent	Occasional	Frequent
	Chest Discomfort	Absent	Occasional	Frequent
	Sweating	Absent	Occasional	Frequent

8. Discussion

In recent years, there have been notable advancements in health monitoring systems. Pendurthi et al. have proposed an innovative pulse sensor-based system that utilizes Arduino and Bolt Wi-Fi for real-time heartbeat monitoring, seamlessly integrating with AWS to provide timely irregularity alerts. Similarly, Akter et al. have presented an ECG monitoring system featuring an AD8232 sensor, Arduino Nano, and NodeMCU, facilitating real-time data transmission and cloud storage, complemented by MATLAB-based analysis tools. Ruman et al. have contributed an Internet of Things (IoT)-based patient monitoring system designed for continuous data collection and cloud storage. Gupta et al. have introduced "HeartCare," a system that leverages machine learning algorithms for real-time heart disease prediction. This collective body of research reflects a paradigm shift in health monitoring, emphasizing the integration of advanced technologies to enhance diagnostic capabilities and provide proactive healthcare solutions.

Aligned with these transformative developments, our health monitoring system employs a sophisticated dual-sensor approach. The MAX30100 sensor meticulously evaluates blood oxygen levels and pulse rates, seamlessly transmitting the acquired data to the Raspberry Pi 3b+ and further to the Blynk IoT app. Concurrently, the AD8232 sensor focuses on ECG measurements, enhancing monitoring capabilities with a direct chest attachment. The ECG Sensor, designed with disposable electrodes, ensures precision in continuous heartbeat measurements. This meticulously designed system caters to the specific needs of medical professionals, incorporating precise electrode placements on the arm and lower-left abdomen pulses. The device also provides a visual guide for users to navigate through key sections of a website, including the home, analysis, and instructions pages. The illustration emphasizes the seamless connectivity between these pages, highlighting their interrelated nature. Specifically, the instructions page is featured, showcasing its comprehensive content that combines a demonstration video with written guidance on effectively using both the portable ECG device and the website. This section serves as a valuable resource for users seeking clear instructions and support.

The analysis page is also depicted in the image, incorporating elements designed to enhance user experience. Notably, a safety meter for health levels is presented, offering users a visual indicator of their well-being. Additionally, an emergency alarm system is showcased, designed to trigger ambulance dispatch and notify family members during critical situations. This feature underscores the website's commitment to user safety, providing a robust system to address emergency scenarios promptly. In essence, our health monitoring system not only exemplifies technological excellence but also embodies a significant stride towards advancing healthcare technologies and contributing to the paradigm shift in patient care.

9. Conclusion

This project stands as a testament to our commitment to advancing healthcare technology through the enhancement of ECG machines. The primary objective revolves around making these devices portable and accessible to a broader population. By developing a portable and accessible ECG machine, we not only facilitate prompt responses from medical professionals and emergency services but also empower individuals to actively monitor their cardiac health. For instance, with optimal health readings, including SpO_2 levels within the range of 95-100%, a heart rate between 60-100 BPM, and normal ECG graph readings, individuals can enhance their understanding of cardiovascular well-being.

The comprehensive heart risk assessment reveals valuable insights into various parameters influencing cardiovascular health. Optimal health readings, including SpO_2 levels within the range of 95-100%, a heart rate between 60-100 BPM, and normal ECG graph readings, indicate a lower risk. Age-related risk categories suggest that individuals aged 20-39 years typically have a lower risk compared to those aged 40-59, and individuals above 60 may face an elevated risk. Medical history, encompassing diabetes, blood pressure, and cholesterol levels, further contributes to risk stratification. Family history plays a crucial role, with the presence of heart issues in close relatives correlating with higher risk levels. Lifestyle factors, such as stress levels, smoking and alcohol habits, and BMI, provide additional layers of information for a comprehensive risk assessment. Lastly, the presence of symptoms like breathlessness, chest discomfort, and excessive sweating serves as crucial indicators. This collective data aids in developing personalized health strategies, allowing individuals to mitigate risks and promote overall cardiovascular well-being. Regular monitoring and lifestyle modifications based on these insights can significantly contribute to proactive heart health management. This approach aligns seamlessly with the comprehensive heart risk assessment presented earlier, allowing individuals to leverage advanced yet affordable healthcare solutions.

10. Future Work

Anticipated advancements in future implementations of the health monitoring system will focus on refining ECG data with improved filtering and incorporating a sudden cardiac arrest (SCA) detector using machine learning. A pulse delivery mechanism driven by machine learning algorithms aims to enhance system responsiveness. Redesigned enclosures and a transition to a stable PCB implementation will address potential errors from external factors and loose connections. Additionally, a dedicated data storage system is planned to securely retain and share ECG data with medical professionals for comprehensive patient care and analysis. These enhancements underline the commitment to advancing accuracy, reliability, and overall utility in healthcare settings.

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