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Design and Development of Heart Vest for Heart health Monitoring Based on Internet of Things (IoT)

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ABSTRAK
IoT-based cardiac monitoring systems face challenges related to both accuracy and convenience. The integration of real-time wearables based on AD8232 and ESP8266 has not been widely explored in practical applications. This research aims to develop an affordable, portable, and reliable heart monitoring solution. Specifically, it focuses on designing and testing the Heart Vest as a real-time heart monitoring system based on IoT and mobile applications. Experimental research was conducted by testing IoT devices using AD8232 and ESP8266 sensors. Data were transmitted to Firebase and visualized through an Android application. Tests on sensor accuracy, data synchronization, and BPM status classification were carried out to verify system reliability. The test results show that the AD8232 sensor achieved an average accuracy of 97.8% (2.20% error rate). Data synchronization between the Heart Vest LCD and the mobile application reached 100%. The system successfully classified heart status (normal, alert, danger) with 100% accuracy and provided real-time alerts via LED and buzzer. These findings demonstrate the reliability of the Heart Vest as an efficient, economical, and responsive real-time monitoring system for non-clinical use. Moreover, the results reinforce the potential of IoT-based wearable systems in cardiac monitoring applications. Future research should include clinical trials and multi-sensor integration to further enhance functionality and clinical accuracy.

Keyword: Heart Vest, AD8232 sensor, ESP8266, heart monitoring, IoT wearable

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INTRODUCTION

Data obtained from the World Health Organization (2024) show that cardiovascular disease (CVD) remains the leading cause of death globally, with fatalities reaching approximately 17.9 million people each year, accounting for about 31% of total global deaths. At the same time, the global cardiac wearables market is projected to grow by 12% annually until 2034, reflecting the rising demand for remote cardiac monitoring solutions. This trend highlights the increasing adoption of wearable technology as an essential tool for early detection of arrhythmia and heart attack risks (Scholte et al., 2024; Nayab et al., 2024). Consequently, the need for wearable devices connected via IoT and capable of providing real-time monitoring has become increasingly relevant and urgent.

Despite the accelerating adoption of wearable devices, current cardiac monitoring systems still face significant challenges. If not addressed, limitations in accuracy and device comfort can lead to delayed arrhythmia detection, rapid disease progression, and higher mortality rates (Ahmad et al., 2025). At the individual level, false-negative results or discomfort may reduce patient compliance, while at the organizational and societal levels, delayed intervention may increase healthcare costs and reduce system efficiency. Without proper intervention, the limitations of remote monitoring could further exacerbate inequalities in access to cardiac healthcare (Christle et al., 2025).

Previous studies have introduced heart rate monitoring devices employing basic technologies to enable early detection of cardiac disorders in real time. Bhattarai et al. (2022) designed a system based on ESP32 and AD8232 sensors to transmit ECG signals to a cloud platform, but it remained limited to laboratory testing without mobile interface integration. Marudhapandi et al. (2019) developed a simple wearable monitoring system using Arduino Uno with a Bluetooth connection; however, the device lacked remote monitoring capabilities and exhibited low energy efficiency. Ortiz et al. (2018) introduced an IoT-based ECG system connected to ThingSpeak, but the output was limited to numerical data, without representative ECG curve visualization. Similarly, Iskandar et al. (2019) designed a portable ECG prototype using Arduino and Bluetooth, but it lacked cloud-based monitoring and integrated mobile applications. Susmitha et al. (2023) utilized ESP8266 to connect the system to a mobile application, though real-time ECG signal processing had not yet been implemented.

In general, while several studies have combined microcontrollers and ECG sensors, few have developed wearable prototypes capable of real-time ECG signal visualization through IoT integration, particularly using AD8232 and ESP8266 components in a smart vest form. This gap underscores the need to develop a simple, power-efficient, affordable, and user-friendly heart monitoring system suitable for use beyond clinical environments.

Although previous studies have made significant contributions, they share common limitations, including the absence of real-time ECG visualization, insufficient mobile integration, and a lack of ergonomic designs appropriate for daily wear. This research addresses these gaps by developing the Heart Vest a smart wearable vest integrating the AD8232 sensor and ESP8266 microcontroller with real-time ECG signal visualization via a mobile application. The novelty of this research lies in the vest-based form factor, which enables more accurate signal acquisition from the torso, combined with seamless IoT integration through Firebase and a user-friendly Android application developed with MIT App Inventor. This system not only provides numerical data but also visualizes ECG waveforms and offers immediate alerts via LED and buzzer, significantly enhancing user responsiveness and convenience.

By addressing these research gaps, the Heart Vest supports a heart health monitoring system that is simple, power-efficient, affordable, and practical for non-clinical settings. This study aims to contribute to the growing body of knowledge on IoT-based health monitoring while offering a scalable and accessible solution for preventive cardiovascular care.

Literature Review

The literature on Internet of Things (IoT)-based heart rate monitoring systems has shown significant growth over the last decade as the demand for real-time, portable, and digitally integrated health devices increases. Recent studies have explored various approaches in the design of wearable and sensor-based monitoring systems to detect cardiovascular parameters such as BPM (beats per minute) and ECG.

The development of wearable devices for IoT-based heart monitoring has resulted in several innovative designs. Edo Agung Nugroho et al. (2024) designed a smart bracelet capable of monitoring heart rate, body temperature, and oxygen saturation using MAX30102 sensors integrated into a watch design. This study emphasized the importance of ergonomic factors in wearable design to support long-term user comfort. Meanwhile, research by Alam et al. (2019) developed an Arduino- and LabVIEW-based ECG monitoring system utilizing Bluetooth HC-05 for data communication, highlighting aspects of signal accuracy and visual interface through a personal computer. Both studies illustrate the transition from static devices to portable systems that are more user-friendly and can be utilized outside medical facilities.

However, wearable designs that fully integrate ECG-based cardiac detection into a vest have not yet been optimally explored. This study contributes uniquely to the field through the development of the Heart Vest—a smart vest that employs the AD8232 sensor and ESP8266 microcontroller to detect biopotential signals in real time. This approach extends the system design paradigm from wrist-based to torso-based devices, allowing for more accurate signal acquisition. The design also incorporates a notification system and an integrated mobile application for displaying monitoring results.

The use of sensors to detect biopotential signals has become a key component in IoT-based cardiac monitoring systems. One sensor that has received particular attention is the AD8232, which is designed to condition ECG signals through advanced filtering and signal amplification. Hakim and Lestari (2019) explained that this sensor employs a three-lead Einthoven configuration to capture high-quality signals, which are then processed into analog outputs readable by a microcontroller. Due to its noise-minimizing properties, the sensor is an ideal choice for wearable biomedical applications.

In terms of data processing, the NodeMCU ESP8266 offers advantages in Wi-Fi integration, enabling real-time data transmission to cloud platforms (Sahtyawan & Wicaksono, 2020). This microcontroller can be programmed using the Arduino IDE and has a compact form factor suitable for embedded system integration. The combination of the AD8232 sensor and NodeMCU ESP8266 reflects a growing trend toward low-power yet high-performance systems capable of accurately capturing and transmitting biomedical signals.

The evolution from desktop-based monitoring systems to mobile application-based platforms has been a crucial milestone in the advancement of IoT technology. Firebase, as a cloud-based real-time data management platform, facilitates synchronous data transmission and retrieval between microcontrollers and Android applications. Within healthcare systems, this functionality enables real-time user condition reporting directly to medical personnel or family members. The integration is further enhanced through the use of MIT App Inventor, a visual-based mobile application development platform that allows users—including non-programmers—to design monitoring applications that interact directly with microcontroller data.

This literature review highlights the evolution of IoT-based heart rate monitoring systems from conventional desktop applications to portable, real-time mobile–cloud platforms. There is a broad consensus that the combination of biopotential sensors (such as AD8232) and network-enabled microcontrollers (such as ESP8266) forms the fundamental architecture of modern cardiac monitoring systems. However, research gaps remain in the development of ergonomic and optimally integrated wearable systems with robust cloud connectivity. Moreover, few studies have implemented smart vest systems that process data directly to Firebase and visualize results via applications developed in MIT App Inventor.

METHOD

This research employs an applied research approach with experimental techniques to design and test a prototype IoT-based heart rate detection system using the Heart Vest. The research design follows a simple experimental structure focusing on the technical and functional validation of hardware and software through several stages: problem formulation, literature study, system design, testing, and data analysis. This approach was chosen because it facilitates the development of a tangible system that can be evaluated and optimized within a real simulation context. The study was conducted purely within the framework of device-level testing.

The prototype was tested under laboratory conditions to verify the hardware's functionality and the reliability of data communication. Although this research does not explicitly classify its variables, based on the context of systems engineering, the independent variable is the IoT device circuit comprising the NodeMCU ESP8266 microcontroller and AD8232 sensor, while the dependent variable is the system output, represented by the heart rate readings displayed on the LCD, transmitted to Firebase, and visualized on the mobile application. The Heart Vest design process is divided into three stages: architectural design, hardware design, and software design.

1. Architecture Design

The design of the data communication architecture in the heart vest system uses IoT technology. Broadly speaking, it includes three platforms connected via an internet connection. Namely the heart vest as an application layer, firebase as a clouds network and smartphone as perception.

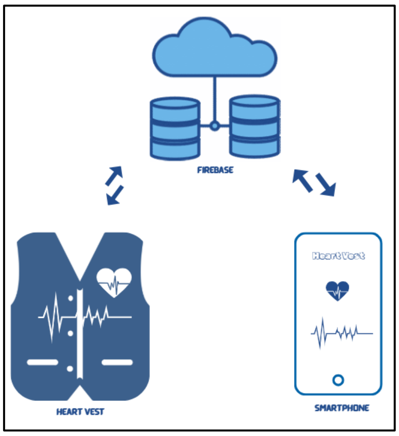


Figure 1. Heart Vest Communication Architecture
Source: Research Documentation (2024)

2. Hardware Design

The next step is hardware design. We will first determine the components that will be used to build the Heart Vest. Next, a hardware circuit schematic is made using Fritzzing software as shown in Figure 2 below.

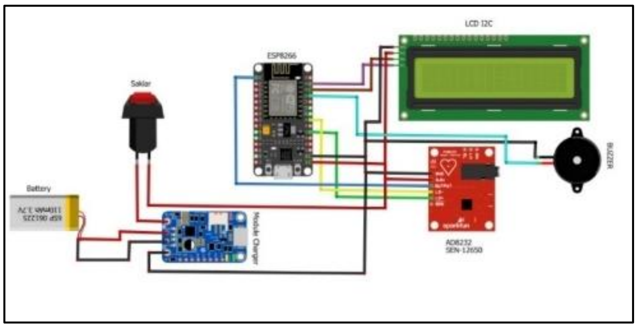


Figure 2. Hardware circuit schematic
Source: Design results using Fritzing Software (2024)

The hardware design of the heart vest utilises the esp8266 microcontroller as its brain and WiFi connection module, the sensor used is AD8232, which functions as a user heart rate detector, and the output of the sensor will be displayed on the I2C LCD. In addition to the data displayed on the LCD, the data is also sent to the Firebase database and will be automatically displayed on the mobile application. When the user's condition is abnormal or in an emergency, the buzzer will sound. In this study, the device is equipped with a battery connected to the charging module, making it easier for users to use.

Furthermore, there is a block diagram that describes the operation of the device, at this stage the function of the device is explained from the device is activated until the sensor reading takes place. The block diagram of the system operation is shown in Figure 3.

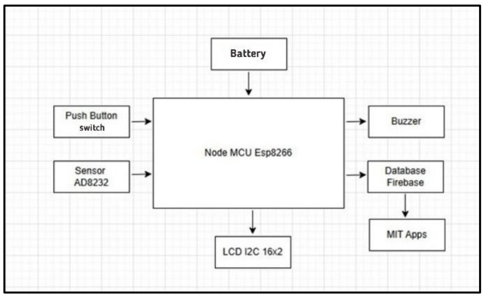


Figure 3. Heart Vest Block Diagram
Source: Research Documentation (2024)

Block diagrams are used to make it easier to design and understand how the device works (Salamah & Munandar, 2020). Based on the block diagram in Figure 4, the battery power input serves as a source of electricity for all components used. The NodeMCU Esp8266 microcontroller acts as the brain in making decisions based on data received from the AD8232 sensor, and push buttons. The AD8232 sensor acts as a heart rate detector which then the sensor reading results are sent to esp8266 as a place to process data. When the heart rate has been detected. Esp8266 will activate the buzzer if the heart rate condition is less than 60 bpm or more than 100 bpm. The bpm data is directly sent to the firebase database to store the realtime data. In addition to the data base, realtime data is also connected to the MITApps application, the data that appears will finally be displayed on the 16x2 I2C LCD.

3. Software Design

The next step is software design that describes the heart vest system process flow cycle. The software used in making the programme for this Smart Hearth Vest is Arduino IDE which plays a role in writing and embedding the programme into the ESP8266 microcontroller.

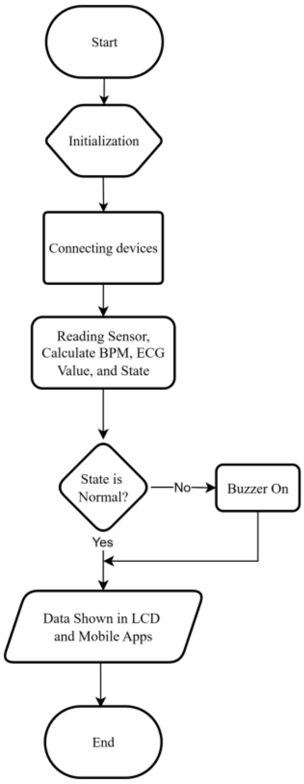


Figure 4. Flowchart Heart Vest
Source: Research Documentation (2024)

The picture above is a flowchart of the heart vest system. Starting from the initialisation of all variables then connecting all devices to the internet. Next, the system will perform the sensor reading process and calculate the bpm and ECG values and health status. If the status shows abnormal, the buzzer will turn on. Furthermore, all data will be displayed on the LCD heart vest and also appear in the mobile application in the form of numerical values and ECG graphs.

RESULTS AND DISCUSSION

Results of Heart Vest Design

Heart Vest is an IoT-based heart rate monitoring smart vest. Heart vest is connected to android application for real-time data monitoring through firebase. ESP8266 as the brain controller will read the AD8232 sensor. To obtain heart rate data, the AD8323 sensor is connected to three electrodes attached to the user's chest (Figure 5). After that, the resulting data will be sent to firebase and displayed on the mobile application.

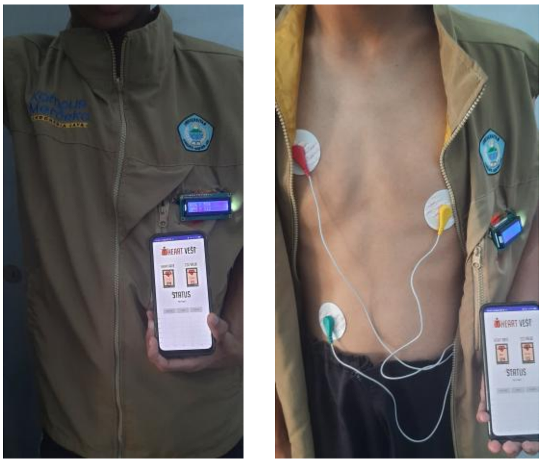


Figure 5. Heart Vest Implementation
Source: Research Documentation (2024)

1. 2. Sensor Accuracy Testing Results

A total of five participants were involved in testing the accuracy of the AD8232 sensor for measuring heart rate. The age of the participants ranged from 15 to 55 years old, with a distribution of two female (40%) and three male (60%) participants. All subjects were tested using the paired method, heart rate measurement using the AD8232 sensor and pulse oximeter simultaneously.

Table 1. BPM Reading Test Results Using the AD8232 Sensor

No.	Age (Year)	Gender	AD8232	Pulse Oximeter	Error
1	25	Female	74	78	5.13%
			80	83	3.61%
			79	80	1.25%
2	15	Male	64	69	7.25%
			68	70	2.86%
			74	73	1.37%
3	20	Male	88	90	2.22%
			90	90	0%
			86	88	2.27%
4	55	Female	93	94	1.06%
			89	90	1.11%
			89	89	0%
5	30	Female	102	100	2%
			100	103	2.91%
			100	100	0%
Average Error					2,20%
Average Accuracy					97,8%

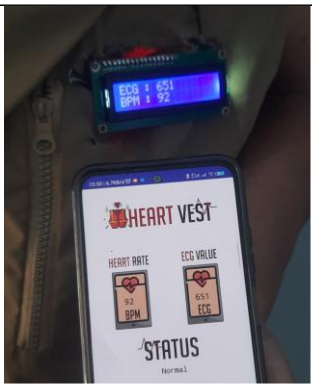
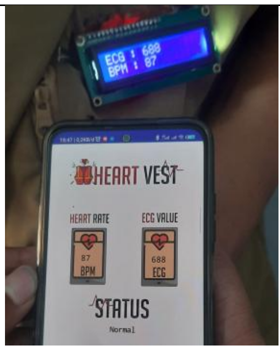
Source: Data Processed by Researchers (2024)

Based on Table 1, the results of heart rate measurements between the AD8232 sensor and the pulse oximeter comparison tool obtained an average error of 2.20% with an accuracy rate of 97.8%. The lowest error rate reached 0% and the highest was 7.25%, while the highest accuracy reached 100% and the lowest was 92.75%.

2. Data Synchronisation Testing Results

Heart vest provides heart health information through the LCD screen on the vest and on the mobile application. Data synchronisation testing is required between the two platforms to ensure they have the same information. At the same time, several data tests were carried out on both platforms and the results can be seen in table 2 below.

Table 2. Results of Data Synchronisation Testing between Heart Vest and Mobile Application

No	Test Documentation	Data Synchronisation Result Accuracy
1		The data on the Heart Vest LCD and mobile app are the same 100%
2		The data on the Heart Vest LCD and mobile app are the same 100%
3		The data on the Heart Vest LCD and mobile app are the same 100%

4		The data on the Heart Vest LCD and mobile app are the same 100%
5		The data on the Heart Vest LCD and mobile app are the same 100%

Source: Data Processed by Researchers (2024)

In Table 3 above, it can be seen that the data sent from the sensor to the LCD screen of the Heart Vest and the mobile application shows a perfect synchronisation level. In five simultaneous tests, all BPM values displayed were identical on both platforms (100% synchronisation accuracy). These results confirm the reliability of the IoT integration between the NodeMCU ESP8266, Firebase, and the Android app.

3. Heart Health Monitoring Testing

Heart vest as a smart vest to monitor heart health has an advantage in early warning of unhealthy heart conditions. The resulting early warning is signalled by a buzzer or LED that lights up if the status condition is abnormal. The buzzer will light up if the status condition is dangerous, while the LED will light up if the status condition is dangerous or alert.

Table 3. Heart Health Monitoring Test Results

No	BPM Value	Status	Buzzer	LED	Description
1	44	Danger	On	On	Appropriate
2	50	Alert	Off	On	Appropriate
3	57	Alert	Off	On	Appropriate
4	72	Normal	Off	Off	Appropriate
5	85	Normal	Off	Off	Appropriate
6	98	Normal	Off	Off	Appropriate
7	105	Alert	Off	On	Appropriate
8	112	Alert	Off	On	Appropriate
9	125	Danger	On	On	Appropriate
10	130	Danger	On	On	Appropriate

Source: Data Processed by Researchers (2024)

The Heart Vest automatically classifies heart rate status into three categories: Normal (60-100 BPM), Alert (45-59 or 101-115 BPM), and Danger (<45 or >115 BPM). Of the 10 status tests conducted, all status classifications and device responses (LED/Buzzer) were in accordance with the system's classification logic (classification accuracy: 100%).

4. Discussion

The main findings of this study show that the AD8232 sensor used in the Heart Vest demonstrates high accuracy in measuring heart rate, with an average error rate of only 2.20% and an accuracy of 97.8%. These results suggest that the Heart Vest can function as a reliable heart monitoring device, particularly for non-clinical monitoring and personal use. In the context of IoT, the perfect data synchronization between the LCD and the mobile application (100%) confirms the reliability of real-time data transmission and visualization through digital platforms. This reinforces the validity of the system as a fully integrated IoT-based monitoring tool.

Theoretically, these findings contribute to strengthening reliability models in IoT-based health monitoring systems. The validation of the AD8232 sensor's accuracy and the successful synchronization of its platforms support the advancement of a heart monitoring framework based on low-cost wearable systems. From a practical perspective, the Heart Vest offers an affordable, portable, and precise solution for daily heart rate monitoring. It is potentially applicable to individuals with low to moderate cardiovascular risk, the elderly population, and athletes. The system's automated response via LED and buzzer provides intuitive early warnings without requiring active user interaction.

CONCLUSION

This study successfully designed and tested the Heart Vest, a real-time, integrated, IoT-based smart vest for heart rate monitoring. The system demonstrated high accuracy (97.8%) in detecting heart rate using the AD8232 sensor and showed reliable performance in data synchronization between the device and the mobile application (100% synchronization). The findings confirm that the integration of the AD8232 sensor, ESP8266 microcontroller, Firebase, and MIT App Inventor can produce an efficient and portable heart rate monitoring system. A novel contribution of this research lies in the design of a vest-based wearable system that not only displays numerical data but also provides heart health status visualization and automated notifications. Practically, the Heart Vest offers an economical, responsive, and user-friendly monitoring solution that is suitable for use outside clinical environments, catering to both the general population and vulnerable groups. This research reinforces the concept of a low-cost, low-power IoT health monitoring system that is scalable for widespread community adoption.

Despite the limitation of the trial being conducted solely in a laboratory setting with a limited number of samples, future research could explore broader clinical validation and the development of machine learning-based intelligent classification algorithms. The methodological approach could be strengthened through long-term field testing and multi-sensor integration (e.g., SpO_2, body temperature). Practitioners are encouraged to adopt the

Heart Vest in community-based daily monitoring programmes with simple user training. Policymakers should support the advancement of locally developed medical IoT devices to improve access to preventive healthcare services. Researchers and technology developers should enhance the design toward AI-based adaptive systems for more precise early detection. In the future, multidisciplinary collaboration should be fostered to accelerate the digital transformation of healthcare services.

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