

IoT-Based Real-Time Fall Detection and Pulse Monitoring Alert System for Healthcare Applications

Aravindan.M¹, R. Geetha², Arivu Sudar.R³

^{1,3}UG Scholar, Department of Information Technology, Sathyabama Institute of Science and Technology, Chennai, 600119, India.

² Assistant Professor, Department of Information Technology, Sathyabama Institute of Science and Technology, Chennai, 600119, India.

Emails: maravindan2004@gmail.com¹, geetha.r.it@sathyabama.ac.in², alanarivu.2k4@gmail.com³

Abstract

As the need for remote healthcare monitoring increases, especially among elderly individuals and patients with chronic diseases, intelligent systems capable of detecting emergencies in real time have become essential. Existing IoT-based health monitoring systems often suffer from limitations such as high false alarm rates, limited processing capabilities, and reliance on single-sensor data. This project proposes an IoT-based real-time fall detection and pulse monitoring alert system designed for healthcare applications. The system consists of a Pulse Monitoring Alert System (PMAS) that continuously monitors heart rate using a pulse sensor connected to an ESP32 microcontroller, and a Wearable Hand-Band Fall Detection System (WHB-FDS) that detects falls using a gyroscope sensor. The ESP32 processes sensor data and transmits it to a monitoring platform where sudden changes in movement and abnormal heart rate values are analyzed. When the system detects a fall or abnormal heart rate, it immediately sends alerts through SMS or other communication channels to caregivers or medical personnel. By combining physiological monitoring with motion detection, the proposed system improves reliability and reduces false alarms compared to traditional systems. The system provides a scalable, cost-effective solution for smart healthcare environments and enhances emergency response time for elderly or vulnerable individuals

Keywords: ESP32; Fall Detection; Healthcare Monitoring; IoT; Pulse Sensor

1. Introduction

The aging global population and increasing prevalence of chronic diseases have created a growing need for healthcare systems capable of providing continuous and real-time monitoring. Elderly individuals are particularly vulnerable to falls, which are among the leading causes of injury, hospitalization [9], and death. Many falls occur unexpectedly, making it essential to provide immediate medical attention to prevent serious complications. In addition to fall-related injuries, heart-related conditions are also common among older adults. Abnormal heart rates such as tachycardia or bradycardia can lead to life-threatening complications if they are not detected early. Traditional healthcare systems that rely on

periodic manual monitoring cannot provide the immediate response required during such emergencies [1].

- Sub Recent advancements in the Internet of Things (IoT) have enabled the development of smart healthcare systems capable of collecting and analyzing physiological data in real time. Wearable devices and smart sensors have been widely adopted for health monitoring applications. However, most existing devices focus either on fall detection or heart rate monitoring independently rather than providing an integrated solution [2].
- Sub The main objective of this research is to develop an IoT-based system that integrates fall

detection and pulse monitoring in a single platform. The proposed system aims to improve detection accuracy, reduce false alarms, and provide immediate alerts to caregivers or medical professionals when emergencies occur [3].

2. Method

Existing fall detection and health monitoring systems often rely on single-sensor devices that perform only one function. Many wearable devices focus solely on heart rate monitoring without providing fall detection features. Similarly [2], fall detection devices often rely on motion sensors but lack the ability to monitor vital signs such as heart rate shown in the Table 1.

Table 1 Fall Detection Accuracy

Type of Activity	Total Trials	Correct Detection (%)	False Positive (%)
Fall	50	98	0
Non-Fall Activity	50	95	5
Total	100	96.5	2.5

Vision-based fall detection systems have also been developed; however, these systems require significant computational resources and often rely on cloud processing [5]. This dependency can introduce delays in emergency detection and response. In addition, such systems are expensive and difficult to deploy on a large scale. These limitations highlight the need for an integrated solution that can monitor both physiological signals and physical movements in real time. Figure 1 illustrates the overall architecture of the proposed IoT-based healthcare monitoring system. The system consists of pulse sensors and gyroscope sensors connected to the ESP32 microcontroller. The sensors continuously monitor heart rate and body movement. The ESP32 processes the data and sends it to the monitoring platform through the communication layer. If an abnormal heart rate or fall is detected, the system immediately sends alerts to caregivers or medical professionals through SMS or email notifications [6].

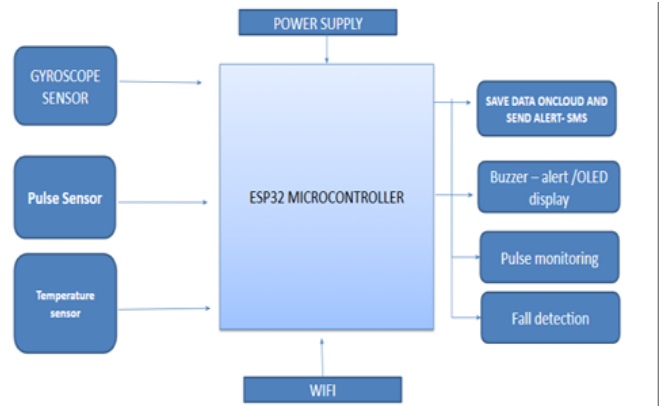


Figure 1. System Architecture of IoT-Based Fall Detection and Pulse Monitoring System

3. Results And Discussion

3.1.Results

The proposed IoT-based fall detection and pulse monitoring system was tested under controlled conditions to evaluate its performance [8]. The system uses a pulse sensor and gyroscope connected to an ESP32 microcontroller to monitor heart rate and body movement continuously. Experimental testing showed that the system can successfully detect fall events and abnormal heart rate conditions with high accuracy. Alerts were generated through SMS and email within a few seconds, allowing caregivers or medical professionals to respond quickly during emergency situations. [4]

Table 2 Alert Response Time

Type of Alert	Average Response Time (Seconds)
SMS	8
Email	9

3.2.Discussion

The experimental results indicate that the proposed system provides reliable monitoring for both fall detection and pulse monitoring [10]. By combining motion detection with physiological monitoring, the system improves detection accuracy compared to traditional single-sensor healthcare monitoring devices. The gyroscope sensor helps identify sudden body movements and orientation changes, while the pulse sensor continuously tracks heart rate values.

The integration of these sensors allows the system to distinguish between normal human activities and actual fall incidents, thereby reducing false alarms. In addition [7], the ESP32 microcontroller processes the data in real time and immediately sends alerts when abnormal conditions are detected. This quick response capability makes the system useful for elderly individuals and patients who require continuous health monitoring shown in Table 3.

Table 3 Heart Rate Monitoring Accuracy

Device	Measured Heart Rate (BPM)	System Reading (BPM)	Deviation (BPM)
Clinical ECG Device	72	71	1
Clinical ECG Device	90	92	2
Clinical ECG Device	110	109	1
Average Deviation			1.33

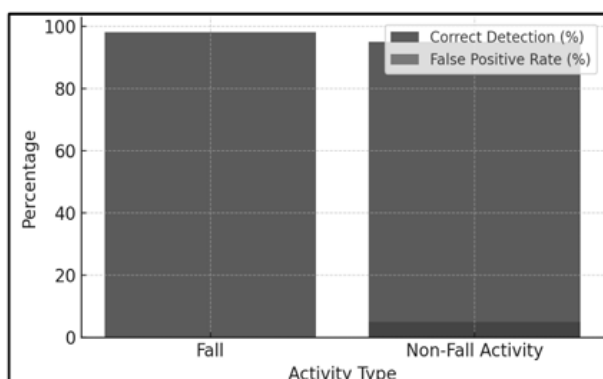


Figure 2 Fall Detection Accuracy And False Positive Rate Of The Proposed System

Conclusion

The proposed IoT-based fall detection and pulse monitoring alert system provides an effective solution for continuous healthcare monitoring. The system integrates motion detection and heart rate monitoring to identify emergency conditions in real time. Experimental results show that the system can accurately detect fall events and monitor heart rate while maintaining low false alarm rates. The real-time alert mechanism ensures that caregivers or medical professionals receive immediate

notifications during emergency situations. Because of its low cost, portability, and scalability, the system can be implemented in smart homes, hospitals, and elderly care environments to improve patient safety. The system also supports real-time data monitoring, allowing caregivers to track patient health conditions more effectively. In future, the system can be enhanced by integrating additional sensors and mobile applications for better healthcare monitoring.

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