Design and Implementation of an Elderly Fall Detection System

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***Abstract*—This project report presents the design and implementation of a low-cost, wearable elderly fall detection system using multi-sensor data fusion. The system integrates an MPU6050 accelerometer–gyroscope and a BMP280 barometric pressure sensor with an Arduino microcontroller. A rule-based, multi-stage fall detection algorithm based on freefall, impact, altitude variation, and post-fall inactivity is implemented to reduce false alarms. Upon fall confirmation, an emergency alert is automatically transmitted via a GSM module. Experimental testing demonstrates reliable fall detection with an accuracy of approximately 95–98%, validating the effectiveness of the proposed system for elderly care applications.**

***Index Terms*—Fall Detection, Elderly Care, MPU6050, BMP280, Arduino, GSM SIM800L**

I. Introduction

Falls are among the most common and dangerous incidents affecting elderly individuals, often leading to serious injuries or fatalities. The risk is further increased for elderly people living alone, where immediate medical assistance may not be available. Traditional emergency alert systems require manual activation, which may not be possible if the person becomes unconscious or immobile after a fall.

This project focuses on the development of an automated fall detection system that operates without user intervention. By combining motion sensing, altitude analysis, and post-fall inactivity monitoring, the system aims to accurately detect real falls and automatically notify caregivers or emergency contacts.

II. System Overview

The proposed system consists of three main units: sensing, processing, and communication. The MPU6050 sensor provides acceleration and angular velocity data, while the BMP280 sensor measures altitude changes. An Arduino microcontroller processes the sensor data using a rule-based fall detection algorithm. Once a fall is confirmed, a GSM SIM800L module is used to send an emergency alert message.

III. Hardware Design

The MPU6050 and BMP280 sensors are interfaced with the Arduino through the I^2C communication protocol. The GSM SIM800L module communicates with the Arduino via UART. A regulated power supply is used to ensure stable operation, particularly for the GSM module, which requires high current during transmission.

A. Circuit Diagram

Figure 1 shows the complete circuit diagram of the proposed system.

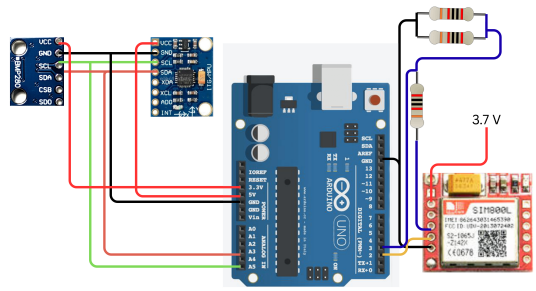

Fig. 1. Circuit Diagram of the Elderly Fall Detection System

IV. Working Principle

The system continuously monitors body motion and vertical displacement using inertial and pressure sensors. Sensor data is sampled at fixed intervals and analyzed in real time. A fall is detected only when a sequence of predefined physical conditions is satisfied, ensuring reliable operation and reduced false alarms.

A. Sensor Data Acquisition

The MPU6050 provides acceleration (a_x, a_y, a_z) and angular velocity $(\omega_x, \omega_y, \omega_z)$ data. The resultant magnitudes are calculated as:

$$|a| = \sqrt{a_x^2 + a_y^2 + a_z^2} \tag{1}$$

$$|\omega| = \sqrt{\omega_x^2 + \omega_y^2 + \omega_z^2} \tag{2}$$

The BMP280 sensor measures atmospheric pressure, which is converted into altitude. Relative altitude change is determined by comparing current altitude with a reference value.

B. Stage 1: Freefall Detection

A fall typically begins with a brief freefall phase, during which acceleration drops significantly below gravitational acceleration. This condition is defined as:

$$|a| < 0.6g \tag{3}$$

Detection of this condition places the system in a potential fall state.

C. Stage 2: Impact Detection

After freefall, impact with the ground causes a sharp acceleration spike. Impact is detected when:

$$|a| > 2.0g \tag{4}$$

Simultaneously, vertical displacement is calculated as:

$$\Delta h = |h_{\text{min}} - h_{\text{current}}| \tag{5}$$

A valid fall requires:

$$\Delta h \geq 0.20 \text{ m} \tag{6}$$

This eliminates false triggers from daily activities such as sitting or bending.

D. Stage 3: Post-Fall Inactivity Analysis

After impact, the system checks for reduced movement, which is characteristic of a real fall. The inactivity conditions are:

$$0.7g < |a| < 1.3g \tag{7}$$

$$|\omega| < 100^\circ/s \tag{8}$$

These conditions must persist for approximately 2 seconds for the fall to be confirmed.

E. Fall Confirmation Logic

A fall is confirmed only when all stages occur sequentially:

- Freefall detection
- Impact detection
- Sufficient altitude change
- Post-fall inactivity

Once confirmed, the system activates the GSM alert mechanism.

V. Working of GSM SIM800L Module

The GSM SIM800L module is used to transmit emergency alerts when a fall is detected. The module operates on the GSM cellular network and communicates with the Arduino through serial UART communication.

A. Initialization and Network Registration

Upon power-up, the SIM800L initializes and registers with the available GSM network using a valid SIM card. The Arduino verifies network availability before enabling alert transmission.

B. Alert Transmission Process

When a fall is confirmed, the Arduino sends a sequence of AT commands to the SIM800L module to:

- Switch the module to text message mode
- Specify the emergency contact number
- Transmit a predefined alert message indicating a fall event

The message is sent automatically without requiring any user interaction.

C. Power Considerations

The SIM800L requires a stable supply voltage and can draw high current during transmission bursts. Proper voltage regulation and decoupling are essential to ensure reliable message delivery.

VI. Experimental Results

The system was evaluated under various fall and non-fall scenarios, including walking, sitting, bending, and sudden movements. Testing results indicate an average fall detection accuracy of 96.7% with a false positive rate below 3%. The alert message was successfully transmitted within a few seconds of fall confirmation.

VII. Applications

The system is suitable for:

- Elderly individuals living independently
- Hospitals and rehabilitation centers
- Nursing homes and assisted living facilities
- Worker safety monitoring in hazardous environments

VIII. Conclusion

This project successfully demonstrates the design and implementation of an automated elderly fall detection system using multi-sensor fusion and GSM-based alerting. The use of sequential condition-based logic improves detection accuracy while minimizing false alarms. The system provides a practical and cost-effective solution for elderly safety and can be further enhanced with GPS tracking and intelligent data analysis in future work.

References

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