Real-Time Fall Detection System for Elderly Care in Old Age Homes Using Raspberry Pi and MPU-6050

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Abstract

This paper presents the design and implementation of a fall detection system aimed at enhancing the safety of elderly individuals in residential care settings. The system integrates an MPU-6050 sensor for capturing acceleration and angular velocity data, which are processed in real-time by a Raspberry Pi 4 server. Upon detecting a fall event, the system activates an alert mechanism, including a buzzer for immediate auditory notification. The design emphasizes simplicity and reliability, with a focus on minimizing response times to improve the overall quality of care. Future enhancements will focus on refining algorithms to optimize accuracy and usability, ensuring effective deployment in care giving environments.

Keywords: Fall detection, Internet of Things, MPU-6050, Raspberry pi

1. Introduction

Falls are a significant cause of injury among the elderly, leading to disabling fractures and complications that can be fatal. Statistics show that most individuals over 75 years old experience at least one fall per year, with 24% sustaining severe injuries. The risk of falling triples for those with Alzheimer's disease. Enhancing elderly care in old age homes can be achieved through the use of sensors that monitor vital signs and activities, transmitting this data to caregivers. This proactive approach can help prevent falls and ensure timely intervention when they do occur.

The consequences of a fall range from minor scrapes to serious fractures, and in some cases, they can lead to death. Prolonged time spent on the floor waiting for help further increases the risk of fatality. Therefore, fall detection is a critical area of research. Many existing fall detection systems utilize accelerometers to identify falls based on changes in acceleration magnitude. When the acceleration exceeds a certain threshold, a fall is detected. These systems aim to quickly alert caregivers or medical personnel, reducing the time an individual spends unattended after a fall and potentially saving lives.

This project aims to contribute to the development of robust fall detection systems tailored for old age homes by collecting relevant parameters, data filtering techniques, and testing approaches from previous studies. Our system employs the MPU-6050 Accelerometer and Gyro Chip, with a NodeMCU sending data to a Raspberry Pi 4, which acts as the server. The MPU-6050 sensor provides detailed information about movement and orientation, while the NodeMCU handles data transmission.

The Raspberry Pi 4 processes the data received from the NodeMCU, analyzing it to detect falls in real-time. This setup avoids the use of complex and computationally intensive algorithms, focusing instead on real-time response and efficient resource use. By leveraging the MPU-6050's high-resolution data and the NodeMCU's wireless communication capabilities, our system ensures that falls are detected promptly and accurately.

Figure 1: Fall

The simplicity and cost-effectiveness of our approach make it ideal for implementation in old age homes, where resources may be limited. By providing a reliable and efficient fall detection system, we aim to improve the quality of life for elderly residents, reducing the risk of severe injuries and fatalities associated with falls. Our system's ability to quickly alert caregivers allows for faster response times, potentially preventing complications that arise from prolonged periods spent on the floor.

In summary, falls are a major health concern for the elderly, with significant consequences ranging from minor injuries to death. Our project aims to enhance elderly care in old age homes through the development of a reliable fall detection system using the MPU-6050 sensor, NodeMCU, and Raspberry Pi 4. This system focuses on real-time detection and efficient use of resources, providing a practical solution to a critical problem.

July 17, 2024

2. Fall Risk Factors

A person can be more or less prone to fall, depending on a number of risk factors and hence a classification based on only age as a parameter is not enough. In fact, medical studies have determined a set of so called risk factors:

2.1. *Intrinsic*

1. Age (over 75)
2. Chronic disease
3. Previous falls
4. Poor balance
5. Low mobility and bone fragility
6. Sight problems
7. Cognitive and dementia problems
8. Parkinson disease
9. Under the influence of drug altering decision making
10. Incorrect lifestyle (inactivity, use of alcohol, obesity)

2.2. *Internal Environment*

1. Need to reach high objects
2. Slipping floors
3. Stairs
4. Incorrect use of shoes and clothes

3. Components

3.1. *Raspberry Pi 4*

The Raspberry Pi 4 acts as the central server in our fall detection system. This single-board computer is equipped with a powerful quad-core ARM Cortex-A72 CPU, running at 1.5GHz. It offers up to 8GB of RAM, providing ample memory for handling multiple tasks simultaneously. The Raspberry Pi 4 includes dual-display support at resolutions up to 4K via micro-HDMI ports, USB 3.0 ports for high-speed peripherals, and Gigabit Ethernet for fast network connectivity.

For our project, the Raspberry Pi 4 processes the data received from the sensors and executes the fall detection algorithm. It is responsible for real-time decision making and sending alerts to caregivers. The device runs a Linux-based operating system, which offers flexibility and a wide range of software tools for development. The GPIO pins on the Raspberry Pi 4 are used for interfacing with other hardware components, such as the MPU-6050 sensor and the NodeMCU.

The setup begins with the Raspberry Pi 4 being positioned in the monitoring room where it serves as the command center for the fall detection system. Its quad-core ARM Cortex-A72 CPU, clocked at 1.5GHz, ensures that the system can handle complex computational tasks efficiently. With up to 8GB of RAM, the Raspberry Pi 4 can manage multiple processes simultaneously, allowing it to process incoming data from the NodeMCU without lag.

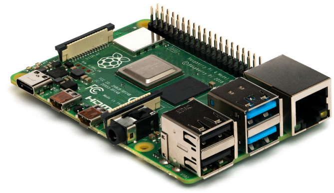

Figure 2: Raspberry pi 4

The dual-display support via micro-HDMI ports enables the Raspberry Pi 4 to connect to two monitors, which can be useful for displaying real-time data and alerts. The USB 3.0 ports facilitate high-speed data transfer from connected peripherals, enhancing the overall system performance. The Gigabit Ethernet port ensures a stable and fast network connection, which is crucial for timely data transmission and alert notifications.

In this project, the fall detection algorithm is central to the system's functionality. The algorithm continuously analyzes acceleration and gyroscope data received from the MPU-6050 sensor attached to the NodeMCU. By comparing the measured values against predefined thresholds, the algorithm can detect significant drops or spikes in acceleration that indicate a fall event. This real-time analysis enables the system to promptly identify and respond to falls.

The GPIO pins on the Raspberry Pi 4 are essential for hardware interfacing. These pins allow the Raspberry Pi 4 to communicate with the MPU-6050 sensor and the NodeMCU, which collects the acceleration and gyroscope data. The GPIO pins can be programmed to handle various input and output signals, making them versatile for different hardware configurations.

Overall, the Raspberry Pi 4 is a robust and efficient choice for the central server in our fall detection system. Its powerful CPU, ample RAM, and versatile connectivity options make it well-suited for processing sensor data and executing complex algorithms in real-time. By leveraging the capabilities of the Raspberry Pi 4, our system can reliably detect falls and promptly notify caregivers, thereby enhancing the safety and well-being of individuals under its watch.

3.2. *MPU-6050*

The ITG MPU-6050 is an advanced sensor that integrates a MEMS (Micro-Electro-Mechanical Systems) accelerometer and a MEMS gyroscope into a single chip. This dual integration allows the sensor to capture both linear acceleration and rotational velocity, making it highly versatile for various applications.

The accelerometer and gyroscope each contain three axes (X, Y, and Z), enabling the sensor to capture movement and orientation in all three dimensions. This comprehensive sensing capability is crucial for tasks such as motion tracking, gesture recognition, and stabilization systems. Each axis features a 16-bit analog-to-digital converter (ADC), providing high-resolution data output. This high resolution enhances the sensor's accuracy and precision, making it suitable for applications requiring detailed motion analysis.

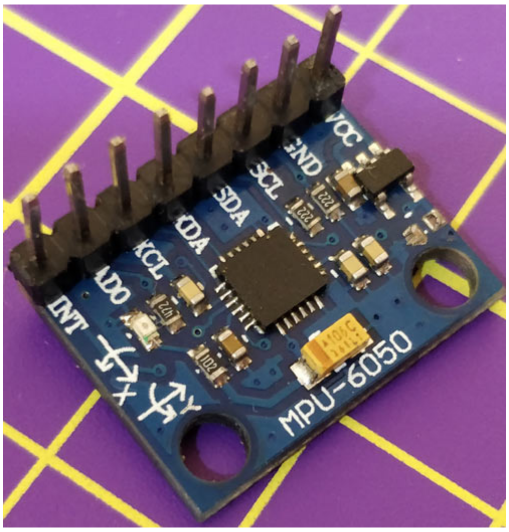

Figure 3: MPU-6050 Module

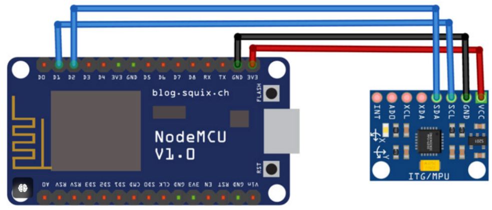

Figure 4: Circuit Diagram

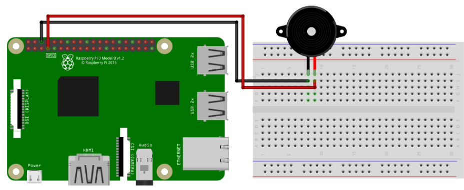
Figure 5: Raspberry pi and buzzer circuit

The MPU-6050 uses the I2C (Inter-Integrated Circuit) protocol for communication. I2C is a multi-master, multi-slave, single-ended, serial computer bus. It is widely used in embedded systems due to its simplicity and efficiency. The I2C protocol requires only two wires for communication: SCL (clock) and SDA (data). These lines facilitate data exchange between the MPU-6050 and the microcontroller or processor, such as the Raspberry Pi 4.

Connecting the MPU-6050 to a Raspberry Pi 4 involves linking the sensor's SCL and SDA pins to the corresponding pins on the Raspberry Pi. This setup allows the Raspberry Pi to receive the high-resolution motion and orientation data from the MPU-6050, enabling the development of sophisticated motion-sensing applications.

The MPU-6050's ability to provide detailed motion and orientation data, combined with the ease of interfacing through the I2C protocol, makes it a valuable component in various fields, including robotics, gaming, and wearable technology.

3.3. NodeMCU

The NodeMCU is an open-source Internet of Things (IoT) platform based on the ESP8266 Wi-Fi module. It provides a simple and cost-effective solution for adding wireless connectivity to various projects, including our fall detection system. The NodeMCU is popular due to its ease of use and flexibility, making it an excellent choice for both beginners and experienced developers.

One of the key advantages of using the NodeMCU is that it can be programmed using the Arduino IDE. This familiar and user-friendly development environment simplifies the process of writing and uploading code to the NodeMCU, allowing developers to quickly prototype and deploy their IoT applications. The availability of numerous libraries and a large community of users further supports development and troubleshooting.

In our fall detection system, the NodeMCU plays a crucial role by collecting data from the MPU-6050 sensor. The MPU-6050 sensor provides high-resolution data on movement and orientation, which the NodeMCU processes and transmits wirelessly to the Raspberry Pi 4. This wireless communication significantly reduces the need for extensive wiring, making the system more streamlined and easier to set up. Additionally, the flexibility in sensor placement allows for more accurate and effective fall detection, as the sensors can be positioned optimally without being constrained by wiring.

The ESP8266 module on the NodeMCU supports the IEEE 802.11 b/g/n Wi-Fi standards, ensuring reliable and fast data transmission. This capability is essential for maintaining a responsive and real-time fall detection system. The stable Wi-Fi connection ensures that the data collected by the MPU-6050 sensor is promptly transmitted to the Raspberry Pi 4 for further processing and analysis.

Overall, the NodeMCU's integration of the ESP8266 Wi-Fi module, compatibility with the Arduino IDE, and support for high-speed wireless communication make it an ideal choice for developing our fall detection system. By leveraging these features, we can create a robust and efficient solution that enhances the safety and well-being of individuals by accurately detecting and responding to falls.

3.4. Buzzer

The buzzer is an audio signaling device used in our fall detection system to provide immediate auditory alerts in the event of a fall. It serves as an additional layer of notification, ensuring that nearby caregivers or residents are instantly aware of an incident.

The buzzer is connected to the Raspberry Pi 4 through one of its GPIO pins. When a fall is detected, the Raspberry Pi 4 sends a signal to the buzzer to produce a loud sound, alerting everyone in the vicinity.

4. Fall Detection Algorithm

The fall detection algorithm calculates the overall acceleration and angular velocity to identify potential falls. First, the total acceleration vector (*Acc*) is computed using the accelerometer data from the MPU-6050:

$$Acc = \sqrt{(Ax)^2 + (Ay)^2 + (Az)^2} \quad (1)$$

where Ax, Ay and Az represent the accelerations in the x, y, and z axes, respectively. Similarly, the angular velocity (w) is derived from the gyroscope data:

$$w = \sqrt{(wx)^2 + (wy)^2 + (wz)^2} \quad (2)$$

where wx, wy, and wz denote the angular velocities in the x, y, and z axes, respectively.

Thresholds are then established to determine potential falls. The Lower Fall Threshold (LFT) is set to detect significant drops in acceleration, suggesting the initiation of a fall. The Upper Fall Threshold (UFT) is defined to identify spikes in acceleration or angular velocity, indicating the impact phase of a fall. These thresholds are derived as follows:

Lower Fall Threshold (LFT): The negative peaks for the resultant acceleration during various activities are referred to as the signal lower peak values (LPVs). The LFT is set at the level of the smallest magnitude lower fall peak (LFP) recorded during these activities.

Upper Fall Threshold (UFT): The positive peaks for the resultant acceleration and angular velocity during various activities are referred to as the signal upper peak values (UPVs). The UFT is set at the level of the smallest magnitude upper peak value (UPV) recorded, corresponding to the peak impact force experienced during a fall.

The system continuously monitors the acceleration and angular velocity data, comparing these values to the predetermined thresholds. If the acceleration drops below the LFT, it implies a potential fall has begun. If the acceleration or angular velocity exceeds the UFT, it signals the impact of the fall. A fall is confirmed when both conditions (LFT and UFT) are met within a short time window, ensuring that the detected event is indeed a fall rather than a false positive from other activities like sitting down quickly.

5. Methodology

In our fall detection system, we have designed and implemented a comprehensive setup that utilizes advanced sensor technology and robust data processing capabilities. Here's a detailed explanation of each component and its operational configuration:

5.1. Wearable Sensor Setup

The core of our system involves integrating the MPU-6050 sensor and the NodeMCU on a breadboard. This setup forms a wearable unit that elderly individuals can comfortably wear, typically positioned around the waist or chest area. The MPU-6050 sensor, equipped with both accelerometer and gyroscope capabilities, captures precise movements in three axes (x, y, and z). This data is crucial for detecting both sudden changes in acceleration and orientation, indicative of a potential fall event.

The NodeMCU, acting as a transmitter, wirelessly sends the sensor data to the central server for real-time processing and analysis. This wireless communication, facilitated by the NodeMCU's Wi-Fi capabilities, ensures flexibility in sensor placement and eliminates the need for cumbersome wiring, enhancing user comfort and mobility.

5.2. Central Server Configuration

A Raspberry Pi 4 serves as the central server and is set up in the monitoring room. Upon receiving data from the NodeMCU, the Raspberry Pi 4 executes the fall detection algorithm in real time. The algorithm analyzes the incoming acceleration and gyroscope data to determine if a fall has occurred. Specifically, it compares the measured acceleration values against predefined thresholds for detecting significant drops or spikes that indicate a fall event.

The system is designed to promptly identify falls by leveraging the high processing capabilities of the Raspberry Pi 4. When data is transmitted from the NodeMCU, it is immediately processed by the Raspberry Pi 4. The fall detection algorithm runs continuously, ensuring that any fall event is quickly recognized. By analyzing both acceleration and gyroscope readings, the algorithm can accurately differentiate between normal movements and potential falls. The predefined thresholds are carefully calibrated to ensure high sensitivity and specificity in detecting falls. Thus, the system provides reliable real-time monitoring and swift response in case of a fall.

5.3. Alert Mechanism

The system incorporates an effective alert mechanism to ensure timely response in case of a fall:

Buzzer Activation: Upon detecting a fall, the Raspberry Pi 4 triggers a buzzer connected to its GPIO pins. The audible alarm from the buzzer provides immediate auditory notification within the vicinity, alerting nearby caregivers or residents to the potential emergency. This immediate response is crucial in reducing the time it takes for assistance to arrive, which can significantly impact the outcome for the individual who has fallen. The loud and distinct sound of the buzzer ensures that even in a noisy environment, the alert will be heard, prompting a quick check on the individual.

Server Notification : Simultaneously, the Raspberry Pi 4 sends a message to the central server. This message includes crucial information such as the patient ID, the exact time when the fall occurred, and the location of the fall within the residential care setting, if available. By transmitting this data to the server, remote caregivers and monitoring personnel are promptly informed of the incident, enabling them to take swift and appropriate action as required. This server notification allows for a coordinated response, ensuring that help is mobilized

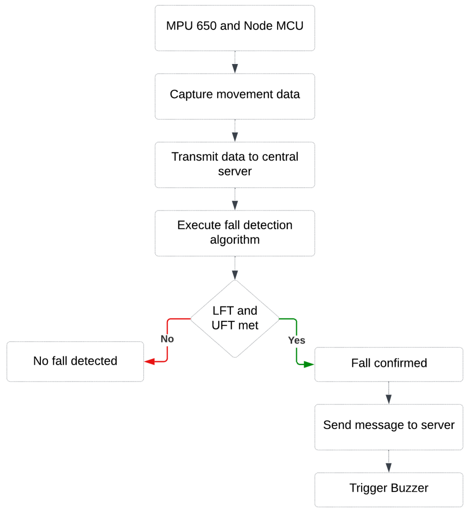

Figure 6: Methodology

quickly and that the incident is logged for further analysis. The integration with the central server also facilitates the collection of data over time, which can be used to identify patterns or frequent fall occurrences, aiding in preventative measures and improving overall care strategies.

6. Conclusion

The development and implementation of our fall detection system represent a significant step forward in enhancing the safety and well-being of elderly individuals in residential care settings. By integrating advanced sensor technology and real-time data processing capabilities, our system offers proactive monitoring and rapid response mechanisms to detect and respond to fall events promptly.

Our fall detection system effectively utilizes the MPU-6050 sensor to capture acceleration and angular velocity data. This data is crucial for reliable detection of falls based on predefined thresholds. By continuously monitoring these parameters, the system ensures that genuine fall events are promptly identified, minimizing the risk of delayed assistance.

Upon detecting a fall, the system activates an alert mechanism. A buzzer provides immediate auditory notification within the vicinity, alerting nearby caregivers or residents. This immediate response is critical in ensuring timely assistance, potentially mitigating the severity of injuries sustained during a fall.

The design and theoretical framework of our fall detection system show promise in addressing the distinct challenges of elderly care environments. We prioritize enhancing algorithm accuracy and minimizing false positives to ensure the system's reliability and effectiveness. Our goal is to refine the system to accurately distinguish between actual falls and other activities, thereby improving the overall performance.

Ensuring usability and acceptance among caregivers and elderly residents is critical to maximizing the system's effectiveness. We are committed to designing an intuitive and user-friendly interface, making it easy for caregivers to interact with the system and respond to alerts. Additionally, we aim to educate and train caregivers and residents on the benefits and operation of the system to foster acceptance and trust.

Moving forward, our focus will be on refining the detection algorithms, enhancing the system's robustness, and integrating additional features to further support caregivers. We are exploring possibilities such as remote monitoring through smartphones or tablets, allowing for continuous oversight even when caregivers are not in the immediate vicinity.

In conclusion, our fall detection system represents a proactive approach to improving elderly care practices. By leveraging advanced sensor technology and real-time data processing, we aim to enhance the safety and quality of life for elderly individuals in residential care settings. Our system's ability to promptly detect falls and activate immediate alerts is a critical step in ensuring timely assistance and reducing the risk of injury. As we continue to develop and refine our system, we remain dedicated to addressing the unique challenges of elderly care and supporting caregivers in their vital roles.

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