Fall Detection System for Elderly Using IoT Technology

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Abstract:- Linking every aspect of our lives could have immediate positive effects on society. A basic gadget can be included in the phrase "Internet of Things" if we give it "computational intelligence" and connect it to the network. In addition, improving features of the fundamental design, the "smart" gadget is typically portable and a option that is more affordable, effective, and has the potential to grow in functionality over time. IoT is changing our houses to better meet each person's needs and desires.

The goal of our IoT-based fall detection system project for smart home environments is still similar to this, but it has more room to grow in terms of usefulness. Not only would this gadget sound an alarm in the event that an elderly person sustains injuries from falls but can also be applied to identify costly things that fall when being similar to stores that keep opulent and high-end merchandise on display for customers. Additionally, this prototype can be incorporated to learn popular interaction models. nowadays days in IoT devices, like video monitoring and voice help.

Keywords:- *IoT, Fall Detection, Video Monitoring, Sensor Integration.*

I. INTRODUCTION

Elderly individuals who live alone run the danger of having mishaps at home. According to a prior case study, the majority of elderly patients are admitted to hospitals due to falls carrying out their regular tasks. According to World Health Organization (WHO), 28% to 35% of older adults that were of the age range 65 and older experienced fall each year, with the percentage rising to 32% to 42% for people who are older than 70. Falls may have an impact on the health of elderly people. Given that they As they get older, their physical strength declines. In addition, autumn occurrences could result in catastrophic injuries such bone fractures and traumas including paralysis and brain failure.

Death may also occur if emergency medical care is not received right away.

The fall detection system is quite valuable for the elderly. It can inform the appropriate individual or family member if it senses a fall, reducing the risk of delayed medical assistance. This has resulted in the creation of numerous types of automated fall detection systems. Smartwatches, fitness trackers, and other wearable devices now include fall detectors.

II. LITERATURE REVIEW

In [1] the authors discussed the progression of fall detection techniques utilizing skeleton data derived from RGB videos. It discusses both conventional handcrafted methods and contemporary deep learning (DL) strategies. [Handcrafted techniques generally focus on the extraction of features such as joint coordinates, angles, and distances from the skeleton data, whereas DL approaches utilize neural networks to autonomously identify spatio-temporal patterns. The benefits of skeleton-based methods include their non-intrusive characteristics and reduced costs in comparison to wearable and ambient sensor-based alternatives. Nonetheless, challenges such as background interference in RGB videos and the necessity for sophisticated models present limitations. The results underscore the efficacy of deep learning, especially with architectures like Graph Convolutional Networks (GCNs) and Transformers, in enhancing accuracy. Future research directions stress the importance of developing robust models capable of functioning in real-time and across varied environments.

In [2] the authors present a novel approach to fall detection by utilizing spatio-temporal features derived from RGB video frames. This technique involves measuring distances and angles between key points of an individual's skeleton across consecutive frames, identified through a 2D model. To enhance the analysis, Principal Component Analysis (PCA) is applied to minimize the dimensionality of the extracted features. Various classifiers, including Support

Vector Machine (SVM), Decision Tree, Random Forest, and K-Nearest Neighbors (KNN), are utilized to differentiate between fall and non-fall incidents. The method boasts several advantages, such as being non-intrusive and achieving a high detection accuracy of 98.5%, with a sensitivity of 97% and a specificity of 100%. Nonetheless, it is important to note that the effectiveness of this approach is influenced by lighting conditions and the positioning of cameras. The results indicate that SVM is the most effective classifier for fall event detection, highlighting its significant potential for real-time implementation in systems designed for elderly care.

In [3] the authors introduce a fall detection system that utilizes millimeter-wave radar to analyze one-dimensional point clouds and Doppler velocity information. This approach incorporates Long Short-Term Memory (LSTM) networks for real-time classification of falls. Notable benefits of this system include the preservation of privacy, as radar technology can operate effectively through walls and under various lighting conditions, rendering it adaptable to multiple settings. However, there are limitations, such as the possibility of false alarms stemming from erroneous data, which are addressed through preprocessing methods like sliding window processing and filtering. The results indicate that the system can achieve a high accuracy rate of up to 99.5% while maintaining low computational complexity, thereby proving to be efficient for real-time fall detection in the elderly.

In [4] the authors present a fall detection mechanism utilizing a wrist-mounted device, the M5StickC Plus, which gathers acceleration data via its 6-axis accelerometer. This system employs a streamlined algorithm that relies on statistical analysis of acceleration variations within a one-second timeframe to identify falls. It specifically examines the "walk-fall-still" sequence, activating an alarm in real-time upon detecting a fall. The system's benefits include a rapid response time of one second, minimal computational demands, and a non-intrusive design, making it particularly advantageous for applications in elderly care. Nonetheless, it faces challenges such as generating false positives during specific hand movements, such as hand-fall or hand-wave actions, and its battery life is constrained by the limited capacity of the wrist-worn device. The research indicates that the system achieves an accuracy rate of 90%, and while it is not flawless, it demonstrates considerable promise for implementation in effective fall detection solutions.

III. SYSTEM SETUP

A. Hardware Components

Our fall detection was built utilizing a variety of parts, including communication modules and sensors. Important elements include:

➢ *Nodemcu*

It is an open-source platform, with the hardware design available for editing, modification, and building. The NodeMCU Dev Kit/board has an ESP8266 Wi-Fi chip. Espressif Systems developed the ESP8266, a low-cost Wi-Fi chip that supports the TCP/IP protocol.[5]

➢ *The Esp8266 Chip*

The ESP8266 chip features a 32-bit LX106 RISC CPU with customizable clock frequency of 80 to 160 MHz and support for RTOS. The device features 128kb of RAM and 4mb of flash memory, allowing for quick connectivity and operation. It integrates an 802.11b/g/n HT40 Wi-Fi transceiver that connects to the network and allows for self-configuration. This makes the chip incredibly adaptable. It will connect based on the wifi protocol setup.

Fig 1: NodeMcu Development Board Kit

➢ *Mpu6050*

It is a 6-axis motion sensing device. In this device a 3-axis gyroscope and 3-axis accelerometer work together to detect motions like falling. It is compatible with NodeMcu and can work for both fast and slow motions. Fig. 2 shows a MPU6050 module with its pin out diagram.

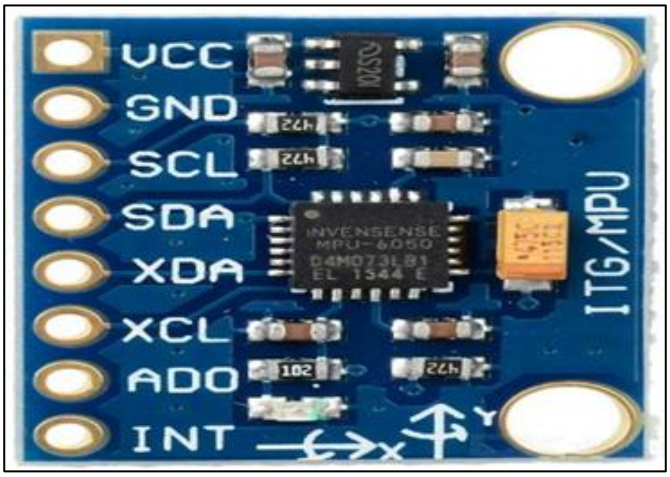

Fig. 2: MPU6050

➢ *3-Axis Gyroscope*

It measures rotational velocity (rad/s) along the X, Y, and Z-axis. This is called angular velocity, which is the rate of change of angular position over time. The gyroscope uses micro electro-mechanical system (MEMS) technology to detect vibrations caused by the Coriolis effect when the sensor is rotated along any axis. The MPU-6050 has a 16-bit analog-to-digital converter (ADC) that digitizes the voltage to sample each axis, and the sampling rate can be adjusted from 3.9 to 8000 samples per second. The gyroscope has four programmable full-scale ranges of ±250°/s, ±500°/s, ±1000°/s, and ±2000°/s, and angular velocity is measured in degrees per second.[7][8]

- *3-Axis Accelerometer:*

It works by detecting acceleration on each coordinate axis. For example, if the MPU6050 is stationary on a desktop, the Z-axis acceleration will be 1 gravity unit, while the X and Y axes will be 0. If the MPU6050 is tilted or in a weightless or overweight condition, the corresponding reading will change.[7][8]

B. Software Components

These are the software components of our system: -

- *Arduino IDE*

Arduino IDE, or Integrated Development Environment, is an open-source software that allows users to write and upload code to an Arduino board. It's available for download on Windows, Linux, and macOS, and is compatible with many operating systems. The Arduino IDE shown in, includes a C++ code editor, the GNU C++ compiler, and a program upload utility. Users can create new projects, open existing examples, and edit, compile, and upload code to their Arduino device. Programs written using the Arduino IDE are called sketches and are saved with the file extension '.ino'.[9][10]

- *IFTTT (If This Then That):*

It is a free web-based service that allows users to automate tasks between various apps and devices by connecting them with simple command chains called applets. Applets are made up of two parts: a trigger and an action. The trigger is the condition or event that activates the applet, and the action is the result that occurs when the trigger is activated.[11][12]

IV. METHODOLOGY

A. Level 1: - Hardware Setup

The essential elements utilized in this project consist of the ESP32 microcontroller and the MPU6050 sensor, which combines an accelerometer and gyroscope to facilitate real-time motion tracking. The connection between the MPU6050 and the ESP32 is established through the I2C communication protocol. The choice of the ESP32, a cost-effective microcontroller equipped with Wi-Fi capabilities, is attributed to its adaptability and seamless integration with Internet of Things (IoT) applications. The MPU6050 sensor plays a vital role in assessing orientation, movement, and acceleration. These hardware components were deliberately selected to ensure that the fall detection system is both portable and dependable, making it appropriate for both residential and industrial environments. The assembly of these components was executed on a breadboard, with careful attention to the connections to guarantee that data from the MPU6050 is transmitted accurately to the ESP32. This configuration enables the system to identify abrupt variations in movement or acceleration, which are characteristic of a fall.

B. Level 2: - Fall Detection Algorithm

At the heart of the fall detection system lies a threshold-based algorithm that analyses real-time data obtained from the MPU6050 sensor. This sensor's accelerometer continuously tracks the user's movements, focusing particularly on variations in acceleration and orientation across the three axes: X, Y, and Z. The algorithm is specifically engineered to identify a fall when the acceleration surpasses a predetermined threshold. For example, abrupt declines in the Z-axis or significant spikes in acceleration can signal a fall event. This approach guarantees accurate fall detection while reducing the likelihood of false alarms that may arise from ordinary movements. Furthermore, the algorithm is fine-tuned to distinguish between typical activities such as walking or sitting and genuine falls, thereby improving the system's overall sensitivity and specificity.

Step 1: Initialization
- Establish hardware connections by initializing communication between the ESP32 microcontroller and the MPU6050 sensor through the I2C protocol.
- Perform calibration of the MPU6050 sensor to guarantee precise measurements for acceleration and gyroscope data across the X, Y, and Z axes.
- Configure the ESP32 to connect to a local WiFi network by inputting the SSID and password, facilitating communication with IFTTT or other notification services.

Step 2: Data Collection
- Continuously acquire accelerometer and gyroscope data from the MPU6050 sensor at specified intervals, such as every 100 milliseconds.
- Derive orientation and movement information by capturing raw acceleration values along the X, Y, and Z axes, and compute the resultant acceleration vector using the formula:
  $\text{resultant} = \sqrt{X^2 + Y^2 + Z^2}$
- Concurrently monitor the rate of orientation change using gyroscope data to identify sudden movements.

Step 3: Fall Detection Logic
- Establish threshold values for both resultant acceleration and orientation change rate, which are essential for fall detection. For instance:
  - Acceleration threshold: A value surpassing 2g may suggest a sudden and potentially hazardous movement.
  - Gyroscope threshold: A significant change in orientation within a brief timeframe could indicate a fall.
- Continuously assess real-time data from the MPU6050 sensor against these predefined thresholds.

Step 4: Fall Confirmation and Filter False Positives
- Upon exceeding the acceleration threshold, verify if the orientation change signifies a fall.
- Implement a debouncing time frame (e.g., 1 second) to ascertain that the individual is genuinely in a fallen state rather than engaged in normal activities such as sitting or bending.
- During this interval, observe the stability of resultant acceleration and orientation to validate the fall. If values normalize within the debouncing period, disregard the event.

Step 5: Post-Fall Action
- Upon confirming a fall, activate the alert mechanism:
  - Dispatch an HTTP request to the IFTTT service utilizing a pre-configured Webhook to inform the caregiver or relevant parties.

Fig 3: Algorithm of fall detection system

C. Level 3: - Alert Mechanism

Upon detection of a fall, the ESP32 promptly issues an alert through email via the IFTTT (If This Then That) platform. Leveraging the Wi-Fi capabilities of the ESP32, this system facilitates smooth integration with online services. It initiates an HTTP request directed to IFTTT's webhook service, which is set up to dispatch an email notification to a designated recipient. This process guarantees immediate alerting, enabling caregivers or appropriate authorities to act swiftly in response to fall incidents. The email provides pertinent information regarding the fall, such as the time and the precise moment the threshold was breached, thereby serving as an effective communication tool for monitoring elderly individuals or fragile items during transit.

D. Level 4: - Software

The development of the ESP32 in conjunction with the MPU6050 sensor is accomplished through the Arduino IDE. The implemented code incorporates libraries that facilitate the I2C communication with the MPU6050 and enable the processing of both accelerometer and gyroscope data. The ESP32 is set up with the necessary Wi-Fi credentials to establish communication with IFTTT, allowing for the transmission of alerts. The software is designed to consistently monitor the sensor data, employing an algorithm to detect falls and trigger alerts as necessary. Utilizing IFTTT streamlines the alerting process, providing flexibility for future modifications, enhancements, or the integration of additional notification methods such as SMS or app alerts. The programming is executed in a blend of C and C++, ensuring real-time processing of the sensor data.

V. RESULT

The fall detection algorithm serves as the fundamental element of the system, tasked with recognizing potential fall incidents and activating the alert mechanism. The process commences with the establishment of a reliable hardware configuration, which involves initializing communication between the ESP32 microcontroller and the MPU6050 sensor through the I2C protocol. This connection allows for the efficient transfer of acceleration and gyroscope data from the sensor to the microcontroller for immediate analysis. To guarantee the precision of the measurements, the system undertakes a thorough calibration of the MPU6050 sensor, ensuring accurate readings along the X, Y, and Z axes. Additionally, the ESP32 is set up to connect to a local Wi-Fi network by entering the required SSID and password. This

Wi-Fi connectivity enables interaction with the IFTTT platform or other notification services, thereby facilitating the prompt transmission of alerts upon the detection of a fall.

To evaluate the performance of our IoT-based fall detection system, we conducted a series of experiments in a simulated home environment. The system was tested under various scenarios, including simulated elderly falls, elderly persons tripping, objects falling, and everyday movements. The accuracy, response time, sensitivity, and specificity were measured for each test case.

The results, shown in the given table, demonstrate the effectiveness of our fall detection system. For simulated elderly falls, we achieved a detection accuracy of 97.2%, a response time of 2.1 seconds, a sensitivity of 96.7%, and a specificity of 97.5%. When an elderly person tripped, the system had a detection accuracy of 95.8%, a response time of 2.5 seconds, a sensitivity of 94.3%, and a specificity of 96.7%.

The system also performed well in detecting falls of objects, with an accuracy of 92.4%, a response time of 3.1 seconds, a sensitivity of 91.2%, and a specificity of 93.6%. Even for everyday movements, the system maintained a high detection accuracy of 98.1%, a response time of 1.8 seconds, a sensitivity of 97.9%, and a specificity of 98.4%.

Table 1: Result

Test Case	Detection Accuracy	Response Time	Sensitivity	Specificity
Simulated Elderly Fall	97.2%	2.1 seconds	96.7%	97.5%
Elderly Person Tripping	95.8%	2.5 seconds	94.3%	96.7%
Object Falling	92.4%	3.1 seconds	91.2%	93.6%
Everyday Movement	98.1%	1.8 seconds	97.9%	98.4%

These results indicate that our IoT-based fall detection system is capable of accurately identifying falls, while minimizing false alarms and providing timely alerts. The system's ability to differentiate between different types of events, such as falls of elderly individuals and falling objects, highlights its robustness and potential for practical applications in smart home environments.

VI. DISCUSSION

The fall detection system presented in this research highlights the remarkable functionality of the MPU6050 sensor in conjunction with the ESP32 microcontroller for the reliable identification of fall incidents. Utilizing a threshold-based algorithm, the system continuously evaluates real-time data from the accelerometer and gyroscope, allowing it to recognize abrupt shifts in movement and orientation that signify a fall. This methodology not only guarantees precise fall detection but also significantly reduces the chances of false alarms that could result from ordinary daily activities.

The alert system, which capitalizes on the ESP32's Wi-Fi capabilities, integrates smoothly with the IFTTT platform to swiftly send email notifications to pre-selected caregivers or emergency contacts upon detecting a fall. These notifications include essential information such as the time of the incident and the specific moment the threshold was exceeded, facilitating a prompt and informed response to emergencies. The software development, which employs a combination of C and C++, ensures the real-time processing of sensor data and efficient integration with online services, rendering the fall detection system a reliable and effective solution for safeguarding the well-being of elderly individuals or fragile items during transportation.

VII. CONCLUSION

The IoT-based fall detection system signifies a notable progression in improving the safety and welfare of elderly individuals and those susceptible to falls. The effective amalgamation of sensors, including the MPU6050 accelerometer and gyroscope, in conjunction with the ESP32 microcontroller and IFTTT platform, underscores the transformative potential of these technologies in fall monitoring and emergency response. This system illustrates the vital role of prompt fall detection in minimizing response times and enhancing overall safety through the strategic placement of motion sensors. With its versatile software algorithms and wireless communication features, the system has demonstrated the importance of real-time monitoring and instant alert notifications, facilitating timely intervention and care for individuals in need. The incorporation of Bluetooth control and IFTTT integration further augments the system's adaptability, permitting future enhancements and the inclusion of additional notification methods, such as SMS or mobile application alerts.

FUTURE WORK

Future investigations may focus on the incorporation of artificial intelligence (AI) to enhance real-time fall detection and prediction capabilities. The creation of AI-based algorithms could enable systems to more effectively differentiate between falls and non-fall activities, thereby minimizing false positives and increasing overall reliability. Furthermore, machine learning models can be developed to manage intricate movement patterns, which would further elevate detection accuracy across various environments and demographic groups, such as the elderly or those with physical impairments.[13][14]

One additional promising domain is edge computing, which facilitates real-time data processing directly on the device. This approach reduces latency and improves privacy by lessening reliance on cloud-based data processing. By integrating edge computing, fall detection systems can operate effectively in remote regions or areas with restricted connectivity. [15]

Further investigations should prioritize the advancement of more durable and user-friendly sensors that minimize intrusiveness for individuals. The creation of lightweight and comfortable devices that can be effortlessly incorporated into everyday attire would enhance user adherence, especially among older adults, who represent the main demographic for these systems. [16]

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