# BITE410L – Machine Learning Course Project Report

## Title of the Project: Fall Detection System

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### Abstract :


This project presents a **real-time IoT-based Fall Detection System** designed to enhance safety for elderly and high-risk individuals. The system is built using a **NodeMCU (ESP8266)** microcontroller and an **MPU6050 accelerometer and gyroscope sensor** to continuously monitor body movements. A lightweight **embedded algorithm** detects abnormal motion patterns and identifies falls based on acceleration and orientation changes. Once a fall is confirmed, the system activates a **buzzer alarm** for local alerting and sends an **SMS notification** to emergency contacts via the **Twilio cloud platform** using Wi-Fi connectivity. This approach ensures fast, automated, and reliable communication during emergencies without requiring manual input. The system provides a **low-cost, efficient, and portable solution** for real-time health monitoring and quick emergency response.


### Introduction:

Falls are one of the leading causes of injury and fatal accidents among elderly and medically vulnerable individuals. In most cases, a delayed response after a fall can lead to serious health complications or even death. Traditional systems, such as manual panic buttons or wearable threshold-based devices, often fail due to human dependency or inaccurate detection. To overcome these limitations, this project introduces an **IoT-based Fall Detection System** that operates **automatically and intelligently** without requiring user intervention.

The proposed system uses a **NodeMCU (ESP8266)** microcontroller connected to an **MPU6050 accelerometer and gyroscope sensor** to continuously monitor body movement and orientation. A **threshold-based decision algorithm** is implemented within the NodeMCU to detect sudden motion changes that correspond to a fall. Upon detection, the system immediately activates a

**buzzer** for local alert and sends an **SMS notification** to emergency contacts using the **Twilio cloud platform** through Wi-Fi.

This integrated approach ensures **real-time detection**, **instant communication**, and **high reliability** while keeping costs low. The project demonstrates how the combination of **IoT and embedded intelligence** can provide a practical, portable, and affordable solution for enhancing personal safety and healthcare monitoring.

## Literature Survey:

Early fall detection systems primarily used simple **threshold-based methods**, where alerts were triggered when the measured acceleration dropped or spiked beyond predefined limits. These approaches were easy to implement and worked efficiently on small microcontrollers but often generated **false alarms** during normal activities like sitting or bending. Later, **machine learning-based models** such as SVM and Random Forest improved accuracy by learning motion patterns from large datasets, though they required more processing power and memory. **Deep learning models** like CNNs and LSTMs achieved higher precision but were unsuitable for real-time use on low-cost IoT devices such as the NodeMCU due to their computational demands. Recent studies emphasize combining **IoT connectivity with simple embedded intelligence** to achieve fast, reliable, and low-cost fall detection. Building on this idea, the proposed system uses a **threshold-based decision algorithm** implemented on the NodeMCU and integrates **Twilio's cloud API** for instant SMS alerts, ensuring both **real-time detection** and **immediate emergency communication** without complex model deployment.

## ProblemStatement:

Falls are a major cause of injury and emergency hospitalizations among elderly individuals, where delayed assistance can lead to severe complications. Existing systems such as manual alert buttons or complex ML-based models either require user intervention or are too resource-heavy for low-cost devices. There is a need for a simple, efficient, and autonomous fall detection system that can operate in real time on lightweight IoT hardware. This project aims to design a NodeMCU-based solution that detects falls using threshold-based motion analysis from an MPU6050 sensor. Upon detection, it provides instant alerts through a buzzer and Twilio SMS notifications, ensuring fast and reliable emergency response**.**

## Proposed System Architecture:

The system consists of hardware and software components integrated for efficient fall detection:

**Hardware Components:-**

1. **NodeMCU(ESP8266)Microcontroller**
   The **NodeMCU ESP8266** acts as the **main control unit** of the system. It continuously reads motion data from the **MPU6050 sensor**, processes it using an embedded fall detection algorithm, and connects to the **internet via Wi-Fi** to send alert messages through the **Twilio cloud API**. Its compact design, built-in Wi-Fi, and sufficient processing speed make it ideal for IoT-based real-time monitoring applications.

2. **MPU6050Sensor(Accelerometer+Gyroscope)**
   The **MPU6050** is a 6-axis **Inertial Measurement Unit (IMU)** that measures acceleration and angular velocity across three axes (X, Y, and Z). The NodeMCU uses these readings to detect sudden changes in acceleration and orientation that indicate a fall. The sensor communicates with the NodeMCU through the **I2C interface** using SDA and SCL pins for accurate and reliable data transmission.

3. **Buzzer(AlertIndicator)**
   A **piezoelectric buzzer** connected to pin **D6** of the NodeMCU provides a **local audible alert** whenever a fall is detected. This helps alert nearby people immediately, even before the SMS notification is sent through Twilio.

4. **PowerSupply(USBCable)**
   The system is powered through a **USB cable** connected to a laptop, adapter, or power bank. This provides a **stable 5V DC supply** to the NodeMCU and connected components, ensuring continuous and reliable operation during demonstrations and testing.

5. **ConnectingWiresandBreadboard**
   **Male-to-female jumper wires** and a **breadboard** are used to establish connections between the **NodeMCU**, **MPU6050 sensor**, and **buzzer**. This setup allows easy prototyping, modification, and troubleshooting without soldering.

**Software Components:-**

1. **Data Acquisition & Embedded Processing (Arduino IDE / C++)**
   The embedded program is developed in **Arduino IDE** using **C++**, where the **NodeMCU (ESP8266)** communicates with the **MPU6050** sensor through the **I2C protocol**. The system continuously collects real-time accelerometer and gyroscope data. The firmware performs preprocessing operations such as calibration, scaling, and calculating parameters

like **resultant acceleration** and **angular velocity**. These values are used to monitor the user's movements and identify patterns that indicate a fall.

2. **Decision Logic for Fall Detection (Embedded Algorithm in C++)**
   Instead of using an external machine learning model, this project implements an **on-device threshold-based fall detection algorithm**. The algorithm uses a **three-stage trigger system** to identify a fall event:
   - **Trigger 1:** Detects sudden free-fall (low acceleration).
   - **Trigger 2:** Detects impact on the ground (high acceleration).
   - **Trigger 3:** Confirms change in orientation using gyroscope readings. When all three triggers are activated in sequence, a **fall event** is confirmed. This rule-based method mimics a lightweight classifier, achieving real-time detection while keeping computation low and ensuring compatibility with the NodeMCU's limited resources.
3. **Twilio Cloud SMS Integration (HTTPS / WiFiClientSecure)**
   The project integrates **Twilio's REST API** for cloud-based alert communication. When a fall is detected, the NodeMCU establishes a **secure HTTPS connection** to Twilio's server using the **WiFiClientSecure** library.
   - **Authentication:** The device authenticates using the **Twilio Account SID** and **Auth Token**, which are Base64 encoded for security.
   - **Alert Message:** A POST request is sent to Twilio's /Messages.json endpoint containing the emergency message and phone numbers.
   - **SMS Delivery:** Twilio instantly sends an **" 🚨 FALL DETECTED"** alert to the predefined contact number, ensuring real-time emergency communication without needing a GSM module.
4. **BuzzerAlertSystem**
   A **buzzer connected to the NodeMCU (D6)** provides an immediate **local audible alert** whenever a fall is detected. The buzzer activates for a few seconds to warn nearby individuals, enhancing user safety even if the Wi-Fi or SMS service is temporarily unavailable.
5. **Wi-FiConnectivity(ESP8266WiFiLibrary)**
   The system connects to a local Wi-Fi network using the **ESP8266WiFi library**. Auto-reconnect mechanisms are implemented to ensure continuous connectivity. The network credentials and status are displayed in the **Serial Monitor** for debugging and verification purposes.

## Experimental Discussion:

The proposed **IoT-based Fall Detection System** was developed and tested using a **NodeMCU ESP8266 microcontroller** and an **MPU6050 accelerometer and gyroscope sensor**. The setup was powered via a **USB connection**, and a **buzzer** was used for immediate local alerts. The NodeMCU was programmed in **Arduino IDE (C++)** to read real-time motion data from the MPU6050 using the I2C protocol. The firmware computes the **resultant acceleration** and **angular velocity** from the raw sensor values and uses a **three-stage threshold algorithm** to detect falls accurately.

During testing, multiple motion activities such as walking, sitting, jumping, and intentional falling were simulated to evaluate the system's accuracy. The three triggers—free fall detection, impact detection, and orientation confirmation—proved effective in minimizing false alarms during normal movements. When a fall event was confirmed, the **buzzer activated for three seconds**, and an **SMS alert** stating *" 🚨 FALL DETECTED! Please check immediately."* was automatically sent to the registered contact number via the **Twilio cloud API** using the NodeMCU's Wi-Fi connection.

The experimental results demonstrated that the system could reliably distinguish between regular movements and actual falls. The **response time** between fall detection and SMS delivery was typically **under 5 seconds**, ensuring prompt notification. The threshold logic provided a **lightweight and energy-efficient** solution suitable for continuous monitoring. Minor calibration of sensor thresholds helped reduce false positives, improving system stability and performance.

Overall, the experiment confirmed that combining **embedded fall detection logic**, **IoT communication via Twilio**, and **real-time sensor monitoring** offers a practical, low-cost, and reliable approach to elderly safety. The results validate that this system can operate autonomously, with minimal delay, and provide immediate alerts without requiring human intervention or complex machine learning models.

## Challenges and Future Work:

**Challenges:-**

During the development and testing of the fall detection system, several practical challenges were encountered:

- **Sensor Calibration:** The MPU6050 required fine-tuning to minimize noise and ensure stable readings, as even slight misalignment affected accuracy.

- **False Positives:** Rapid movements like sitting or bending sometimes triggered false fall alerts, requiring careful adjustment of threshold values.
- **Wi-Fi Connectivity:** The system's dependence on Wi-Fi for Twilio communication occasionally led to delays in message delivery when the connection was weak.
- **Power Management:** Continuous data monitoring increased power consumption when powered via USB, limiting portability without battery support.
- **Environmental Variations:** Sensor sensitivity was affected by placement and movement patterns, requiring manual recalibration for different users.

**Future Work:-**

To improve accuracy and expand functionality, several enhancements can be implemented in the future:

- **Integration of GPS:** Adding a GPS module would allow automatic location sharing with caregivers in SMS alerts.
- **Cloud Data Logging:** Platforms like **ThingSpeak** or **Blynk** can be integrated to store and visualize fall events for long-term monitoring.
- **Mobile App Interface:** Developing an Android or iOS app would allow caregivers to receive live notifications and view user status remotely.
- **Hybrid Detection Algorithm:** Combining threshold logic with lightweight **machine learning models (TinyML)** could further improve detection accuracy while maintaining efficiency.
- **Battery-Powered Operation:** Incorporating a rechargeable Li-ion battery would make the system fully portable and wearable for real-world use.

## Conclusion:

The proposed **IoT-based Fall Detection System** successfully demonstrates an efficient and low-cost solution for monitoring and ensuring the safety of elderly and vulnerable individuals. Using a **NodeMCU ESP8266** microcontroller and an **MPU6050 accelerometer and gyroscope sensor**, the system continuously tracks motion and orientation changes to detect potential falls. A simple yet effective **threshold-based algorithm** is implemented to identify abnormal movements, providing accurate results with minimal processing power.

When a fall is detected, the system immediately activates a **buzzer for local alert** and sends an **SMS notification through Twilio's cloud platform**, ensuring quick emergency response even when caregivers are not nearby. The experimental results confirm that the system performs reliably under real-time conditions with low latency and high responsiveness.

This project proves that by integrating **embedded decision logic** with **IoT-based communication**, a practical and deployable fall detection system can be built without relying on complex machine learning models. Future enhancements such as **GPS integration, cloud data logging, and mobile app connectivity** can further improve the system's functionality, making it a valuable tool for **smart healthcare and assisted living applications**.

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