IoT-Based Elderly Person Fall Detection and Emergency Alert System

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Abstract - *The rapid growth of the elderly population has increased the demand for intelligent healthcare technologies capable of ensuring safety and timely medical assistance. Falls among senior citizens are considered one of the major causes of severe injuries, hospitalization, and loss of independence. This research presents an IoT-enabled Elderly Fall Detection and Emergency Alert System designed to provide continuous monitoring and immediate emergency response. The proposed framework integrates wearable sensors, motion analysis modules, and machine learning techniques to identify abnormal body movements associated with falls. Accelerometer and gyroscope data are collected in real time and processed using classification algorithms to distinguish normal daily activities from accidental fall events with improved precision. Once a fall is detected, the system automatically transmits an emergency notification along with the user's geographic location to caregivers or medical personnel through a wireless communication network. In addition to fall recognition, the system supports basic health monitoring features that enhance elderly safety and independent living. The proposed model emphasizes low-cost implementation, rapid response capability, energy efficiency, and user comfort, making it suitable for home-based healthcare environments. Experimental evaluation demonstrates that the system achieves reliable detection performance with reduced false alarm rates compared to conventional monitoring approaches. The developed solution contributes toward smart healthcare infrastructure by combining Internet of Things technology, real-time data processing, and intelligent alert mechanisms for protecting elderly individuals in emergency situations.*

Keywords - Elderly Fall Detection, Internet of Things (IoT), Emergency Alert System, Machine Learning, Wearable Sensors, Health Monitoring, Smart Healthcare, Real-Time Monitoring.

1. INTRODUCTION

The continuous growth of the elderly population across the world has created major challenges in healthcare monitoring and emergency response systems. Aging individuals are more vulnerable to accidental falls because of reduced muscle strength, poor balance control, neurological disorders, and chronic medical conditions. Falls are considered one of the leading causes of severe injuries, fractures, disability, hospitalization, and mortality among older adults [1], [2]. According to recent healthcare studies, nearly one-third of people above the age of 65 experience at least one fall every year, and the risk increases significantly with age [3], [4]. Delayed medical attention after a fall can worsen injuries and may lead to life-threatening situations, especially for elderly people living independently.

To address these issues, researchers have focused on developing intelligent fall detection and monitoring systems capable of providing immediate emergency assistance. Early fall detection systems primarily depended on manual observation and conventional alarm devices, which lacked reliability and continuous monitoring capabilities [5]. With advancements in wireless communication, wearable electronics, sensor technology, and the Internet of Things (IoT), modern healthcare systems are becoming smarter, more responsive, and more efficient [6]. IoT-based healthcare solutions allow interconnected sensors and smart devices to continuously collect physiological and motion-related information for real-time analysis and decision-making [7].

Several approaches have been proposed for fall detection, including wearable sensor-based systems, environmental sensing techniques, and image-processing-based surveillance systems [8]. Wearable systems commonly use accelerometers and gyroscopes embedded in smart watches or body-mounted devices to analyze body movement and identify abnormal activities associated with falls [9]. Image-based systems utilize computer vision and deep learning algorithms to monitor posture and movement patterns using cameras installed in indoor environments [10]. Although these systems demonstrate promising accuracy, challenges such as false alarms, computational complexity, privacy concerns, and user discomfort still remain major research issues [11].

Machine learning and deep learning techniques have significantly enhanced the performance of modern fall detection systems. Algorithms such as Support Vector Machine (SVM), K-Nearest Neighbor (KNN), Random Forest, Convolutional Neural Networks (CNN), and Long Short-Term Memory (LSTM) networks are widely used for distinguishing fall events from normal daily activities

[12], [13]. Deep learning models can automatically extract meaningful features from sensor and video data, improving classification accuracy and reducing detection errors [14]. In addition, sensor fusion methods combining wearable sensors, radar modules, and camera-based monitoring have shown improved robustness and reliability in real-time environments [15].

Recent studies have also emphasized the importance of integrating emergency alert mechanisms with fall detection frameworks. Smart healthcare systems equipped with GSM, GPS, cloud platforms, and mobile applications can instantly notify caregivers, hospitals, or family members when an emergency situation occurs [16]. Furthermore, wearable health monitoring systems are capable of tracking heart rate, oxygen saturation, body temperature, and physical activity simultaneously, thereby supporting comprehensive elderly healthcare management [17].

The proposed research presents an IoT-enabled Elderly Fall Detection and Emergency Alert System designed to improve the safety and independence of elderly individuals. The system integrates wearable sensors, machine learning algorithms, and wireless communication technologies to detect falls accurately and provide rapid emergency notifications. The objective of the proposed framework is to minimize response time, reduce false alarms, and ensure reliable real-time monitoring through an efficient and cost-effective healthcare solution.

2. SYSTEM DESIGN

The system design of the proposed IoT-Based Elderly Person Fall Detection and Emergency Alert System is focused on offering on going health monitoring, precise fall detection, and quick emergency response for older adults. It combines motion sensing, health tracking, and wireless communication technologies to enhance the safety and ability of elderly people to live independently.

The system keeps collecting data about body movements and physical signs through multiple sensors connected to the ESP32 microcontroller. It reviews this information right away to detect any strange movements or if someone has fallen. When a fall is detected, the system automatically sends out an emergency alert and shares the user's location with their caregivers or family through messages.

The system is divided into two main parts: the hardware design and the software design. The hardware part includes sensors, communication components, display screens, and controllers that collect data and send out alerts. The software part handles data analysis, detects falls, connects with sensors, and uses IoT technology to monitor in real time and respond to emergencies. The system is built to be dependable, affordable, easy to carry, and good for use in smart healthcare settings.

2.1 Hardware Design

The hardware design of the proposed IoT-Based Elderly Person Fall Detection and Emergency Alert System uses various sensing, communication, and alert modules to accurately detect falls and quickly respond to emergencies. The system includes an ESP32 microcontroller, motion sensors, and health monitoring sensors, communication modules, display units, and alert devices. These hardware parts works together to keep a close watch on the movement of the elderly person’s body and their vital health signs.
The ESP32-Wroom serves as the main brain of the system, handling data from the sensors, processing it, and connecting to the internet through IoT. The MPU6050 sensor helps detect sudden movement, changes in position, and impacts that could indicate a fall. A pulse sensor checks the heart rate, and the DHT11 sensor measures body temperature and the surrounding environment. In case of an emergency, GSM and GPS modules are used to send alerts along with the user's current location. The ESP32-CAM module takes pictures to confirm the situation when needed. A buzzer and an LCD screen also provide local sound and visual alerts. The system is built to be easy to carry, dependable, inexpensive, and well-suited for smart healthcare use.

Table 1: Hardware Components

Sr. No.	Name of Component	Model Number	Function
1.	Microcontroller	ESP32-Wroom, Arduino Nano	Main controller used for sensor data processing and IoT communication
2.	Accelerometer & Gyroscope Sensor	ADXL335	Detects body movement, orientation, and fall events
3.	Pulse Sensor	Pulse Sensor Module	Monitors heart rate of the user
4.	Temperature Sensor	DHT11	Measures temperature and humidity
5.	Camera Module	ESP32-CAM	Captures Videos for visual verification during emergencies

6.	GSM Module	SIM800L / GSM Module	Sends SMS alerts to caregivers or family members
7.	GPS Module	NEO-6M GPS	Provides real-time location tracking
8.	LCD Display	16×2 LCD	Displays system status and alert messages
9.	Buzzer	Active Buzzer Module	Generates audio alert when fall is detected

2.2 Software Design

The software part of the proposed IoT-Based Elderly Person Fall Detection and Emergency Alert System is made using Embedded C in the Arduino IDE. This software handles real-time data processing, fall detection, sending emergency alerts, and monitoring through IoT. It keeps checking the data from sensors to spot unusual movements and possible falls with very little delay.

When a fall is found, the software starts the alert system and sends urgent messages, including the user's location, to caregivers or family. The system also lets people watch things in real-time using the Thing Speak IoT platform. On this platform, values like heart rate and temperature are shown with graphs using X and Y axes, making it easier to analyse health information from a distance.

For building and seeing how the system works, Tinker Cad is used to design and test the hardware circuits. Canvas is used to create the block diagram and show the whole project. The software is made to be easy to use, dependable, and efficient for smart healthcare purposes.

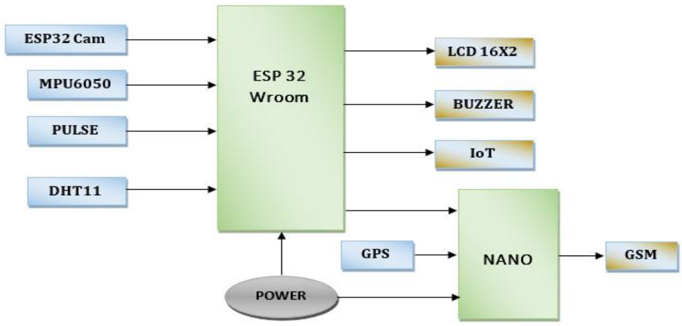

Fig-1 : Block Diagram

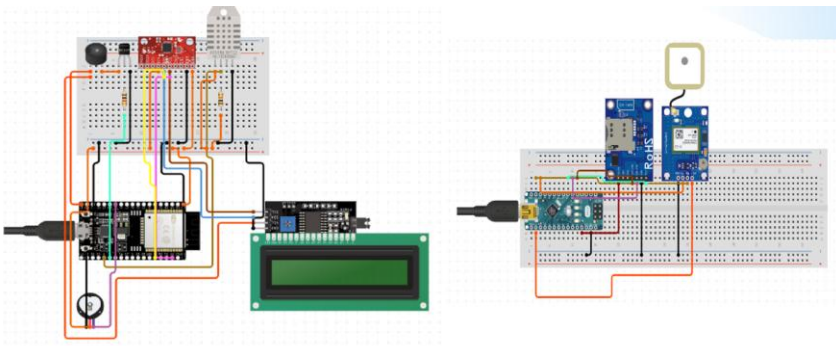

Fig – 2 : Connection Diagram

3. WORKING

During everyday activities like walking, standing, or sitting, the motion sensors show steady and predictable readings. But when someone falls, their body suddenly changes speed and moves in a different way. These unusual movements are picked up by the accelerometer and gyroscope sensors. The microcontroller keeps checking the sensor data and compares it with set limits. If the movement seems like a fall, the system checks more information, such as how the body is positioned and how long it stays still. Once a fall is confirmed, the system starts an emergency response. A buzzer makes a loud sound to get attention, and the GSM module sends a message to set contacts. At the same time, the GPS module finds the person's location so caregivers can get there quickly. Combining motion sensing, smart data analysis, and wireless communication helps the system detect falls and provide fast help, making it safer and better for elderly people.

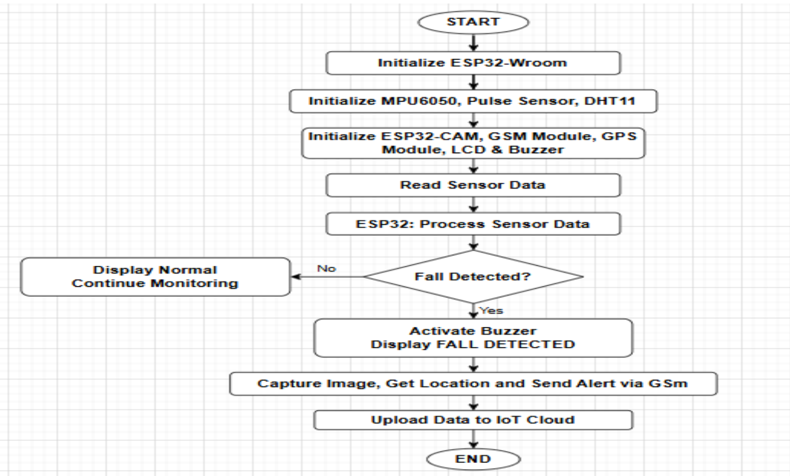

Fig 3: Working Flow Diagram

4. RESULT

4.1. Normal Condition Monitoring Result

During normal operating conditions, the proposed IoT-Based Elderly Person Fall Detection and Emergency Alert System continuously monitored body movements and health parameters without generating any false emergency alerts. The system processed sensor data in real time and maintained stable performance throughout the monitoring process. The LCD display indicated normal system status, while the buzzer remained inactive in the absence of any fall event. Additionally, pulse rate and temperature data were successfully uploaded to the Thing Speak IoT platform, where real-time graphical representations were displayed using X-axis and Y-axis plots for continuous remote health monitoring.

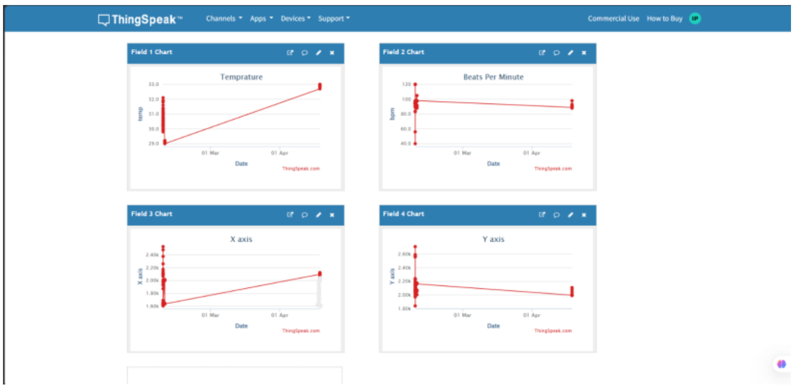

Fig 4 : Normal Condition Graph

4.2 X-Axis Disturbance Detection Result

When the X-axis value of the accelerometer and gyroscope sensor was disturbed beyond the predefined threshold range, the system successfully identified the abnormal body movement and treated it as a possible fall condition. The ESP32 processed the sudden variation in sensor orientation in real time and immediately activated the alert mechanism. The buzzer generated an audio warning, and emergency notifications along with the user's location details were prepared for transmission. The sensor readings were also updated on the Thing Speak platform, where the variation in X-axis movement could be observed graphically through real-time data visualization.

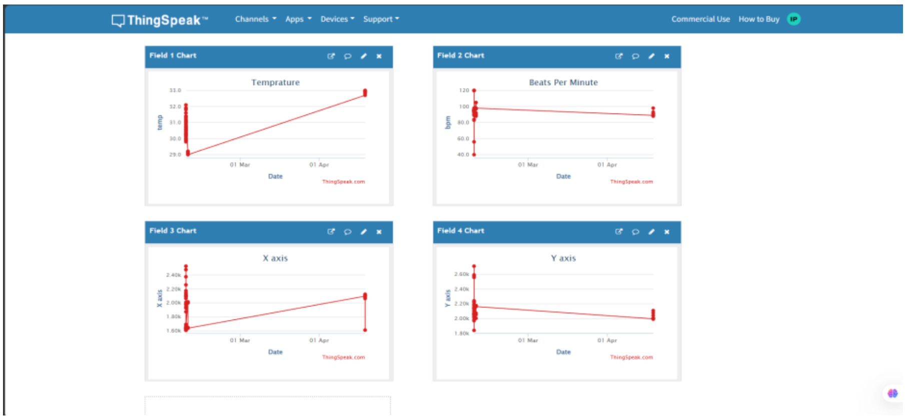

Fig 5 – X-axis Disturbance graph

4.3 Y-Axis Disturbance Detection Result

When the Y-axis value of the accelerometer and gyroscope sensor exceeded the predefined threshold limit, the system successfully detected abnormal movement associated with an unstable body posture or possible fall event. The ESP32 continuously monitored the sensor readings and processed the sudden change in Y-axis orientation in real time. Upon detection, the system activated the emergency alert mechanism, including buzzer notification and emergency message generation. The disturbance data was also updated on the Thing Speak IoT platform, where the Y-axis variation was displayed graphically for real-time monitoring and analysis.

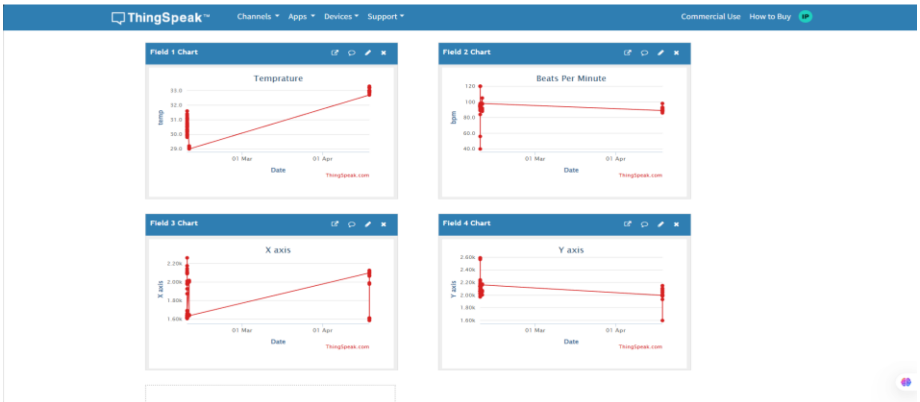

Fig 6 - Y-axis Disturbance graph

4.4. Pulse Rate Disturbance Result

When abnormal pulse rate values were detected beyond the normal threshold range, the system successfully identified the irregular health condition and activated the monitoring process immediately. The pulse sensor continuously transmitted heart rate data to the ESP32, where the readings were analyzed in real time. Upon detecting abnormal pulse variations, the system generated an alert indication and updated the health status on the LCD display. The pulse data was also uploaded to the Thing Speak IoT platform, where real-time graphical visualization using X-axis and Y-axis plots allowed continuous remote monitoring of the user's health condition.

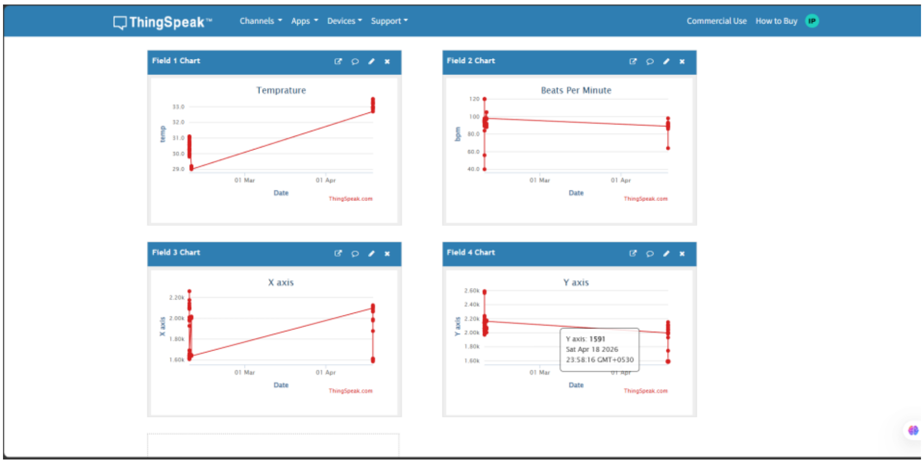

Fig 7 – Pulse Rate Disturbance Graph

4.5 Temperature Disturbance Result

When the temperature value exceeded the predefined normal range, the system successfully detected the abnormal health condition and initiated the monitoring and alert process. The temperature sensor continuously measured the user's body temperature, and the ESP32 processed the sensor readings in real time. Upon detecting unusual temperature variations, the system updated the alert status on the LCD display and activated the necessary notification mechanism. The temperature data was also uploaded to the Thing Speak IoT platform, where real-time graphical representation using X-axis and Y-axis plots enabled continuous remote health monitoring and analysis

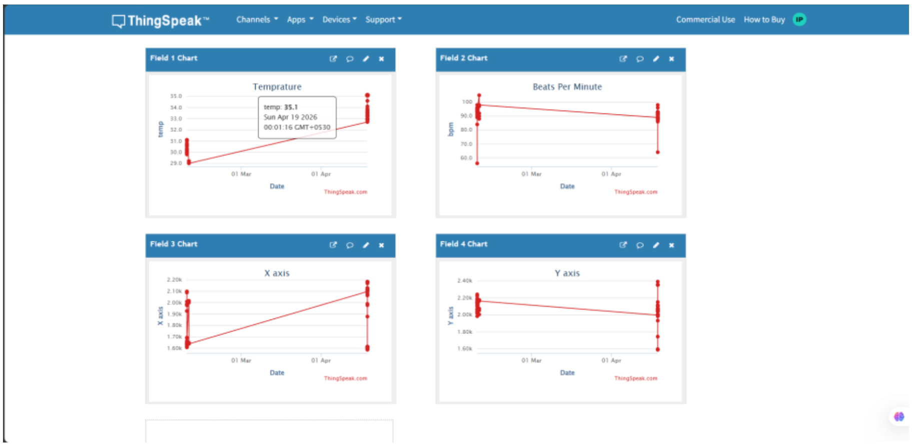

Fig 8 – Temperature Disturbance Graph

4.6 GSM Emergency Alert Message Result

The GSM module successfully transmitted an emergency alert message immediately after detecting a fall event. The SMS contained the alert notification along with the real-time GPS coordinates and a Google Maps link for accurate location tracking. By accessing the provided map link, caregivers or family members can quickly identify the exact location of the elderly person and provide immediate medical assistance during emergency situations.

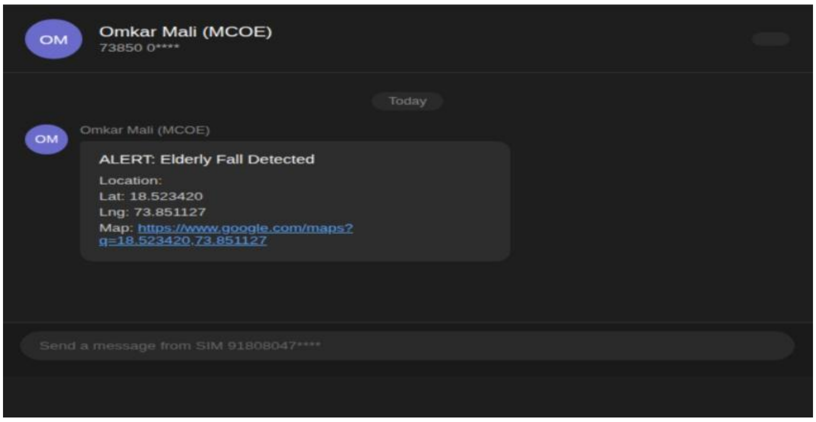

Fig 9 – SMS Alert

4.7 Real-Time GPS Location Tracking Result

The proposed system successfully tracked and displayed the exact location of the elderly person after detecting a fall event. The GPS module generated real-time location coordinates and shared them through a Google Maps link using the GSM module. The above image shows the navigation path from the current location to the detected fall location, demonstrating the system's ability to provide accurate location tracking and quick emergency assistance.

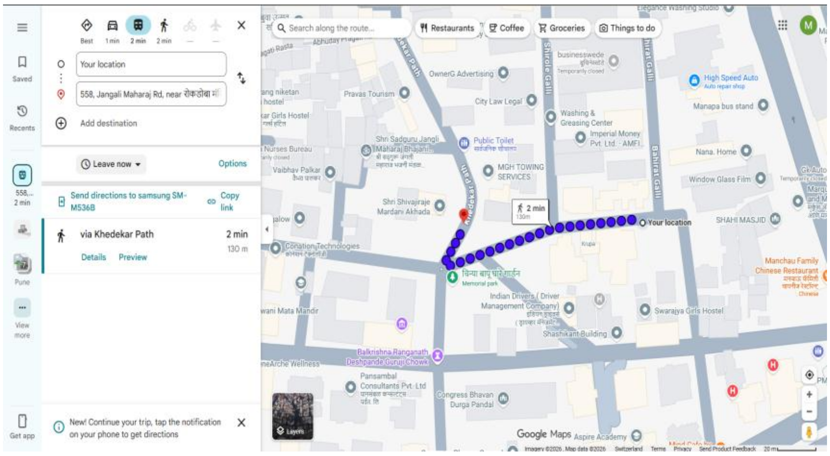

Fig 10 – Fall Detection location

5. FUTURE SCOPE

1. Integration of Advanced AI and Machine Learning Algorithms

Advanced artificial intelligence techniques can be integrated to improve fall detection accuracy and reduce false alarm generation during normal daily activities.

2. Development of Mobile Application for Remote Monitoring

A dedicated mobile application can be developed to provide real-time health monitoring, emergency notifications, and live location tracking for caregivers and family members.

3. Cloud-Based Healthcare Data Storage and Analysis

Cloud integration can be implemented for secure storage of health records and long-term analysis of user health data for predictive healthcare monitoring.

4. Miniaturization into Wearable Smart Devices

The complete system can be converted into a compact wearable device such as a smartwatch or smart band for improved portability and user comfort.

5. Voice Assistance and Two-Way Communication Support

Future systems can include voice alert features and two-way communication capabilities to allow elderly users to communicate directly with caregivers during emergency situations.

6. CONCLUSION

The proposed IoT-Based Elderly Person Fall Detection and Emergency Alert System present an intelligent, reliable, and cost-effective solution for improving the safety and healthcare monitoring of elderly individuals. Falls are one of the major health risks faced by senior citizens and mobility-impaired patients, often resulting in severe injuries and delayed medical assistance. To overcome these challenges, the developed system integrates motion sensing, health monitoring, GPS tracking, and wireless communication technologies to provide continuous real-time monitoring and rapid emergency response.

The system continuously monitors body movements using accelerometer and gyroscope sensors and accurately detects abnormal movements associated with fall events. In addition to fall detection, the system also monitors important health parameters such as pulse rate and temperature, enabling better healthcare supervision for elderly users. Whenever abnormal movement or health conditions are detected, the system immediately activates the emergency alert mechanism and sends notifications along with the user's real-time location details to caregivers or family members through GSM communication.

The integration of the Thing Speak IoT platform further enhances the effectiveness of the system by providing remote monitoring and graphical visualization of sensor data through X-axis and Y-axis plots. This feature allows continuous observation of pulse rate and temperature values from anywhere through an internet-based interface. The system also provides local audio and visual alerts using a buzzer and LCD display, ensuring immediate attention during emergency situations.

The developed prototype demonstrates stable operation, real-time response capability, portability, and low implementation cost, making it suitable for smart healthcare and assisted living applications. The use of ESP32 technology, IoT communication, and integrated health monitoring improves the overall reliability and efficiency of the proposed system. Overall, the project successfully achieves its objective of enhancing elderly safety, reducing emergency response time, and supporting independent living through intelligent healthcare monitoring and emergency alert technology.

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