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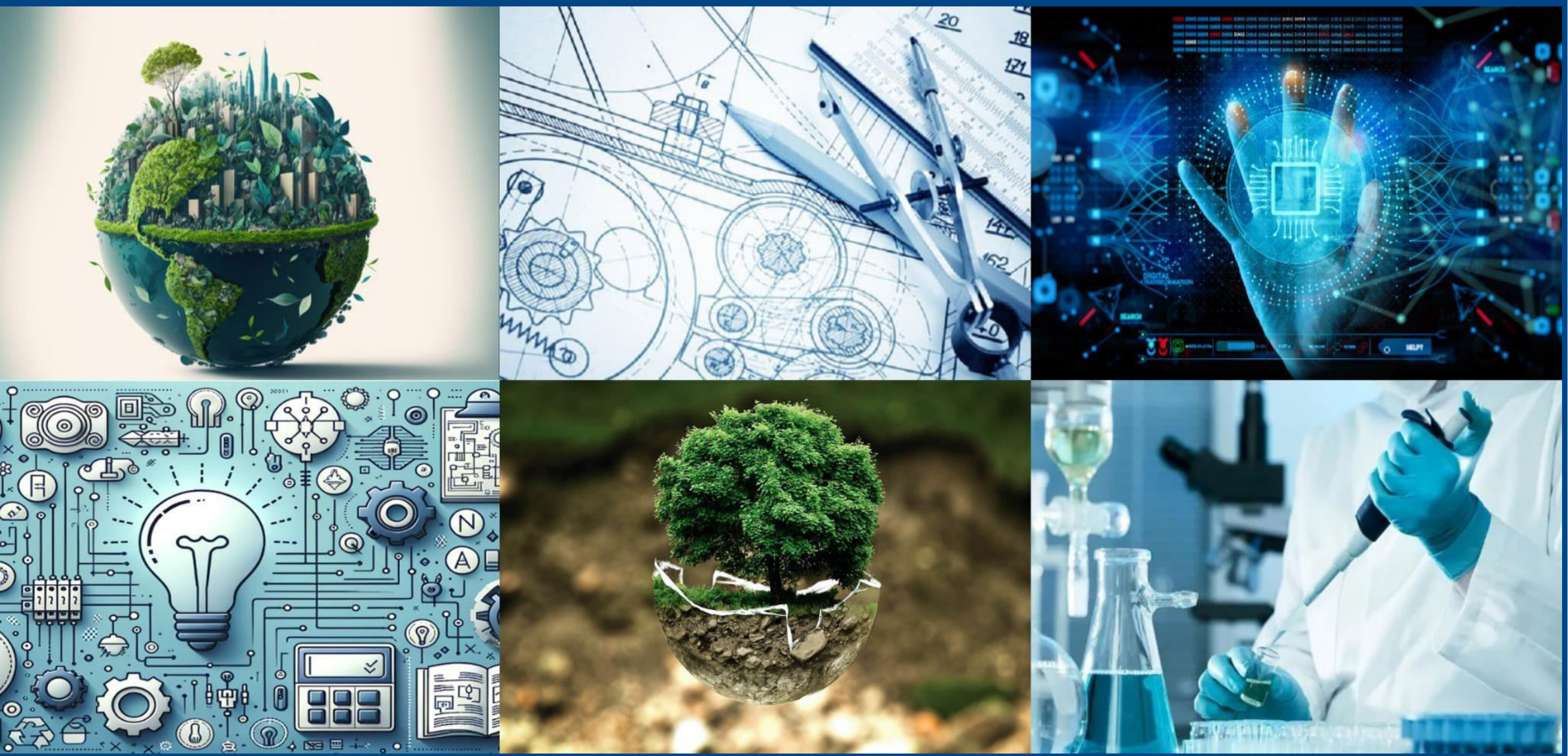

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IoT Based Vehicle Accident Detection and Alert System

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ABSTRACT: Road accidents remain a pressing global concern, often leading to severe injuries and fatalities due to delays in emergency response. To address this challenge, an IoT-Based Accident Detection and Alert System is proposed, leveraging smart sensing and real-time communication technologies to enable rapid accident reporting. The system integrates an accelerometer and vibration sensor to continuously monitor vehicle dynamics and detect collision events or abnormal acceleration patterns. Upon accident detection, the microcontroller automatically retrieves the vehicle's GPS coordinates and transmits an alert message to pre-configured emergency contacts or authorities via GSM or IoT cloud services. This ensures immediate notification even when victims are unable to seek help, thereby reducing response time and improving chances of timely medical assistance. A local alert mechanism using a buzzer or LED provides instant feedback on system activation. The solution is cost-effective, reliable, and adaptable across different vehicle types. By enhancing detection accuracy and enabling automated communication, the system contributes to improved road safety. Future enhancements may include mobile app integration, camera-based monitoring, and AI-driven accident prediction, paving the way for a more intelligent transportation ecosystem.

KEYWORDS: IoT, Accident Detection, Emergency Response, GPS, GSM Communication, Vehicle Safety, Real-Time Monitoring, Intelligent Transportation System.

I. INTRODUCTION

In today's rapidly expanding transportation ecosystem, road accidents have emerged as a critical global issue, contributing to a significant number of injuries, disabilities, and fatalities each year. Numerous studies emphasize that the first few minutes following an accident—commonly referred to as the *"golden hour"*—are vital for saving lives. Unfortunately, delayed reporting and the absence of timely medical intervention often prevent victims from receiving immediate assistance, underscoring the urgent need for an automated and efficient accident detection solution.[1] The advent of the Internet of Things (IoT) has enabled the interconnection of sensors, devices, and communication networks, creating intelligent systems capable of real-time monitoring and data sharing. IoT technology provides an ideal platform for accident detection by facilitating continuous vehicle surveillance and instant transmission of critical information. An IoT-based accident detection system integrates accelerometers, vibration sensors, microcontrollers, GPS modules, and communication interfaces to identify unusual acceleration, sudden impacts, or vehicle roll-over events.[2] This project proposes an **IoT-Based Accident Detection and Alert System** designed to automatically detect accidents and send immediate notifications to emergency contacts or authorities. Operating independently without human intervention, the system ensures rapid response even when victims are incapacitated. By transmitting precise GPS coordinates, rescue teams can quickly locate the accident site and initiate medical support. The system is versatile, suitable for personal vehicles, commercial fleets, public transportation, and smart city safety infrastructure.[3] The primary objective of this work is to enhance road safety by reducing emergency response times, improving the accuracy of accident reporting, and ensuring timely medical assistance. Future advancements, such as AI-driven accident prediction, camera-based monitoring, and mobile application integration, can further evolve this system into a comprehensive intelligent transportation solution for next-generation smart cities.

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II. AIM AND OBJECTIVES

Aim:
The primary aim of this project is to design and implement an **IoT-Based Accident Detection and Alert System** that can automatically identify vehicular accidents and promptly notify emergency services or pre-configured contacts with accurate location information, thereby reducing response time and improving chances of timely medical assistance.

Objectives:
The following objectives are defined:

- **Accident Detection:** Develop a system that utilizes accelerometers and vibration sensors to continuously monitor vehicle dynamics and detect collision events, abnormal acceleration, or roll-over situations.
- **Real-Time Location Tracking:** Integrate GPS modules to acquire precise geographical coordinates of the accident site for accurate reporting.
- **Automated Communication:** Implement GSM or IoT cloud-based communication modules to transmit accident alerts and location details to emergency contacts or authorities without human intervention.
- **Local Alert Mechanism:** Provide immediate feedback through a buzzer or LED indicator to confirm system activation at the accident site.
- **Cost-Effective and Scalable Design:** Ensure the system is affordable, reliable, and adaptable for different vehicle types, including personal cars, commercial fleets, and public transport.
- **Future Enhancements:** Explore advanced features such as AI-driven accident prediction, camera-based monitoring, and mobile application integration to evolve the system into a comprehensive intelligent transportation solution.

III. PROPOSED ARCHITECTURE

The proposed system is an Intelligent Access Control System that implements multi-factor authentication using RFID card verification and fingerprint recognition. It is designed to ensure that only authorized individuals gain access to secure areas, thereby improving security, accuracy, and operational efficiency.

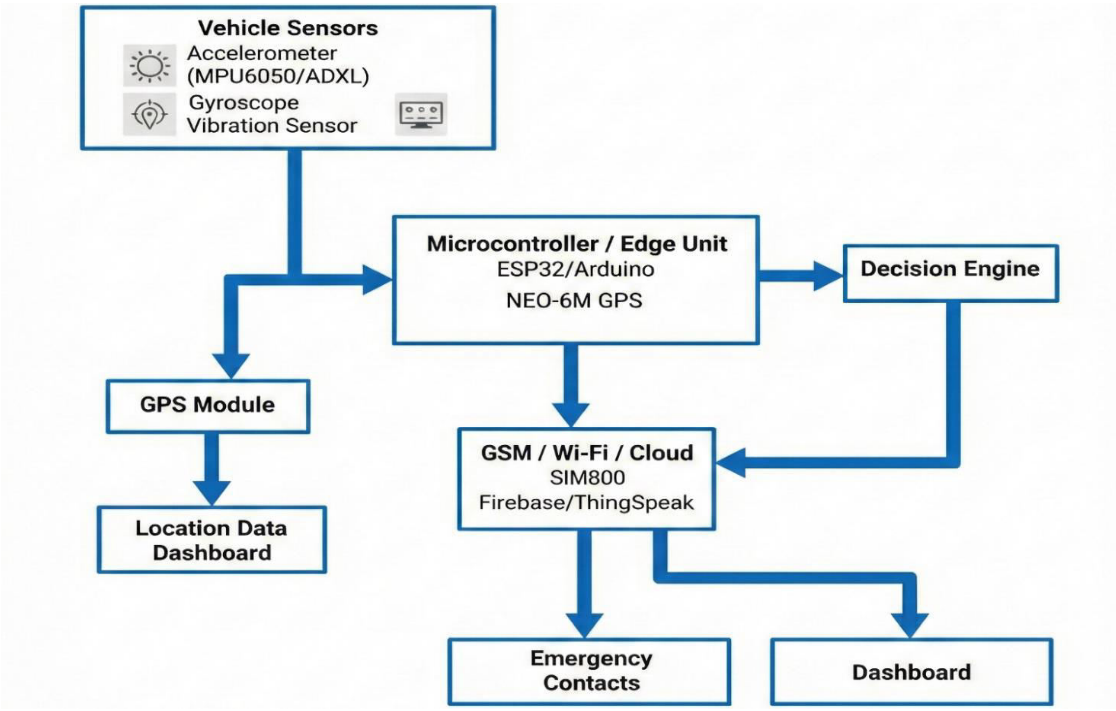

Fig.3.1. System Architecture of IoT-based vehicle accident detection and alert system.

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A. Sensor Module

The sensor module consists of an accelerometer, a gyroscope, and a vibration sensor mounted on the vehicle. These sensors continuously monitor parameters such as acceleration, tilt angle, orientation, and sudden vibrations. The collected sensor data helps in identifying abnormal motion patterns such as collisions, rollovers, or severe impacts.

B. Edge Processing Unit

An ESP32/Arduino microcontroller acts as the edge processing unit. It receives raw sensor data and performs preprocessing, filtering, and threshold-based analysis to minimize noise and false detections. Edge-level processing ensures low latency and enables faster emergency response without complete dependency on cloud computation.

C. GPS Module

The system employs a NEO-6M GPS module to obtain real-time geographical coordinates of the vehicle. Latitude and longitude information is continuously updated and transmitted during emergency conditions, enabling accurate vehicle tracking and location identification.

D. Decision Engine

The decision engine evaluates sensor readings using predefined thresholds and logical conditions. Parameters such as sudden deceleration, excessive vibration, and abnormal tilt angles are analyzed to classify the vehicle state as normal or emergency. Upon detection of an emergency event, the system triggers the alert mechanism.

E. Communication and Cloud Layer

The communication layer utilizes GSM (SIM800) or Wi-Fi connectivity to transmit processed data to cloud platforms such as Firebase or Thing Speak. This layer ensures reliable data transmission, remote monitoring, and real-time synchronization between the vehicle unit and cloud services.

F. User Interface and Alert System

The cloud platform supports a location data dashboard and an emergency contacts dashboard. The location dashboard displays real-time vehicle position on a map interface, while the emergency dashboard automatically sends alerts containing accident information and GPS coordinates to predefined emergency contacts via SMS or cloud notifications.

IV. METHODOLOGY

The methodology of the proposed IoT-based vehicle accident detection and alert system is designed to ensure reliable accident detection, real-time location tracking, and rapid emergency notification. The system integrates multiple sensing, processing, and communication modules operating in a layered architecture.

Block Diagram:

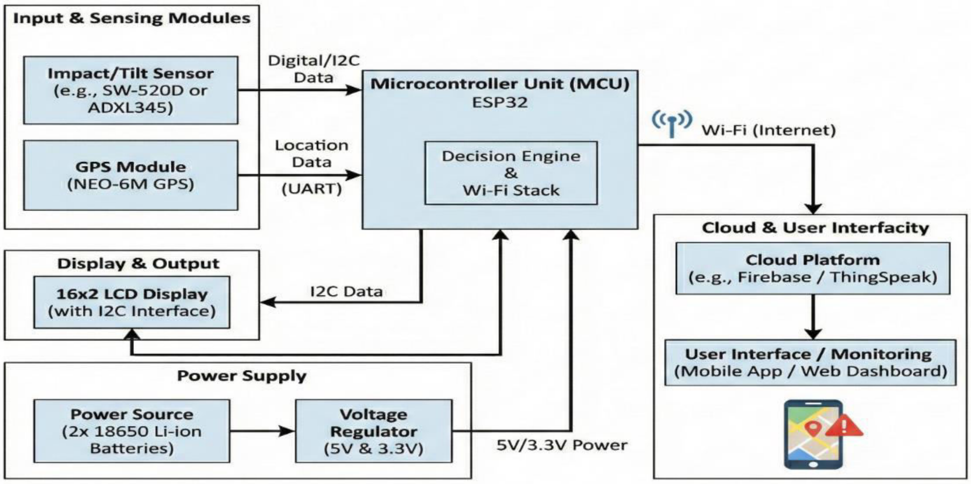

Fig.4.1. Block diagram of the proposed IoT-based vehicle accident detection and alert system.

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A. System Architecture Overview

The overall architecture of the proposed system is illustrated in **Fig. 4.2**, which depicts the interaction among the sensing modules, processing unit, communication layer, and user interface. The system employs an **ESP32 microcontroller** as the core processing unit. It is interfaced with motion sensors, a GPS module, GSM/Wi-Fi communication modules, display units, and regulated power supply components to ensure reliable system operation.

B. Hardware Design and Circuit Implementation

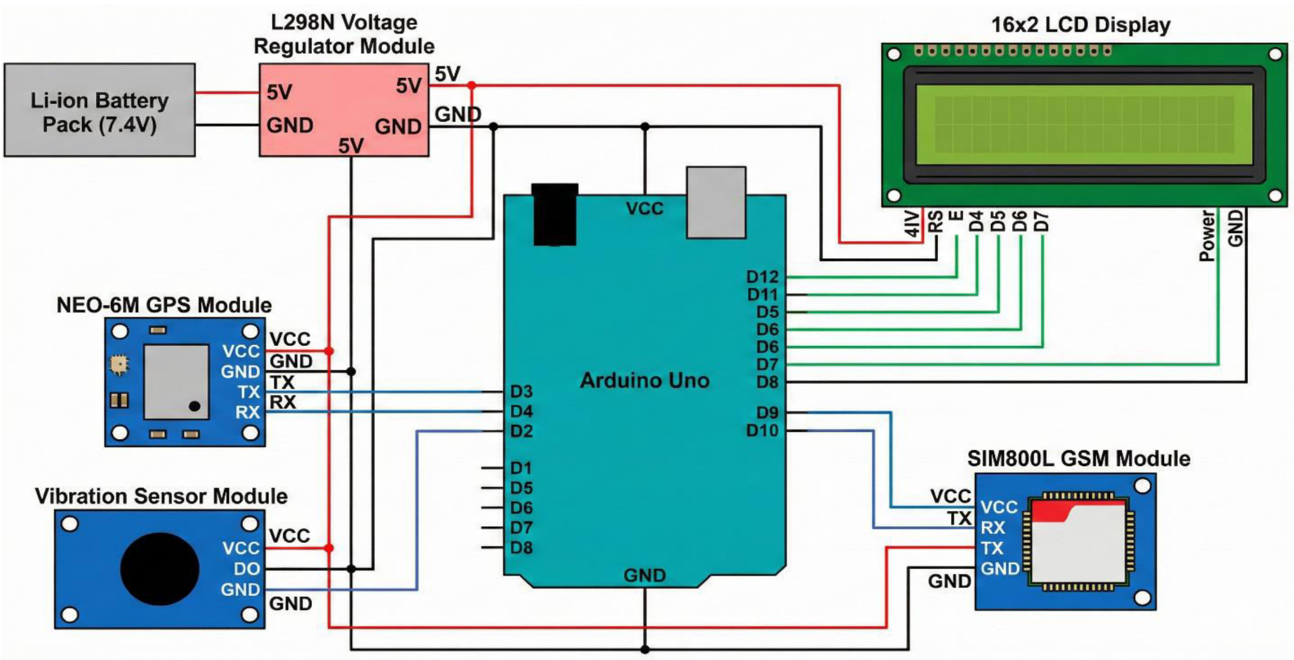

Fig. 4.2. Hardware circuit diagram of the IoT-based vehicle accident detection and alert system.

The hardware setup consists of an ESP32 microcontroller connected to an MPU6050 accelerometer and gyroscope sensor for motion detection, a NEO-6M GPS module for real-time location acquisition, and a SIM800 GSM module for emergency communication. A 16×2 LCD display is used to provide real-time system status and location information. The circuit is powered using a regulated dual 18650 battery supply providing 5 V and 3.3 V outputs.

C. Sensing and Data Acquisition

The sensing layer continuously monitors vehicle motion parameters such as acceleration, angular velocity, and vibration intensity. The MPU6050 sensor communicates with the ESP32 using the I²C protocol, while the GPS module transmits latitude and longitude data via UART. All sensor data is sampled in real time and forwarded to the processing unit for analysis.

D. Accident Detection Algorithm

An embedded decision-making algorithm is implemented on the ESP32 to detect accident events. The algorithm compares real-time sensor values against predefined threshold limits.

- If sensor readings remain within normal limits, the system continues monitoring.
- If acceleration or vibration exceeds the threshold, the system classifies the event as an accident.

This threshold-based approach reduces false positives caused by normal road conditions.

E. Alert Generation and Communication

Once an accident is detected, the ESP32 triggers the alert module. Emergency messages containing accident information and GPS coordinates are transmitted using GSM or Wi-Fi connectivity. A Google Maps link is generated using the acquired latitude and longitude values, allowing emergency contacts to quickly locate the accident site.

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F. User Interface and Monitoring

The system provides a local **web-based user interface** using the ESP32 in **Access Point (AP) mode**. Users can access the interface through a smartphone or laptop to trigger alerts, view accident-related data, and share location information. Additionally, cloud platforms such as **Firebase or ThingSpeak** can be integrated for remote monitoring, data storage, and visualization.

G. Emergency Response Workflow

The emergency alert is received by predefined contacts in the form of **SMS or notification messages**. The embedded Google Maps location link allows rapid identification of the accident location. This significantly improves emergency response time and enhances the probability of timely assistance, thereby increasing the chances of saving lives.

V. FLOWCHART

The system initiates by performing the initialization of all integrated modules. Subsequently, it executes continuous monitoring of the vibration sensor to detect abnormal events. Upon identification of an accident, the system acquires the corresponding GPS coordinates, which are simultaneously rendered on the LCD display for real-time visualization. Furthermore, an emergency alert containing the precise location details is transmitted via the GSM communication module to designated recipients, thereby ensuring timely assistance.

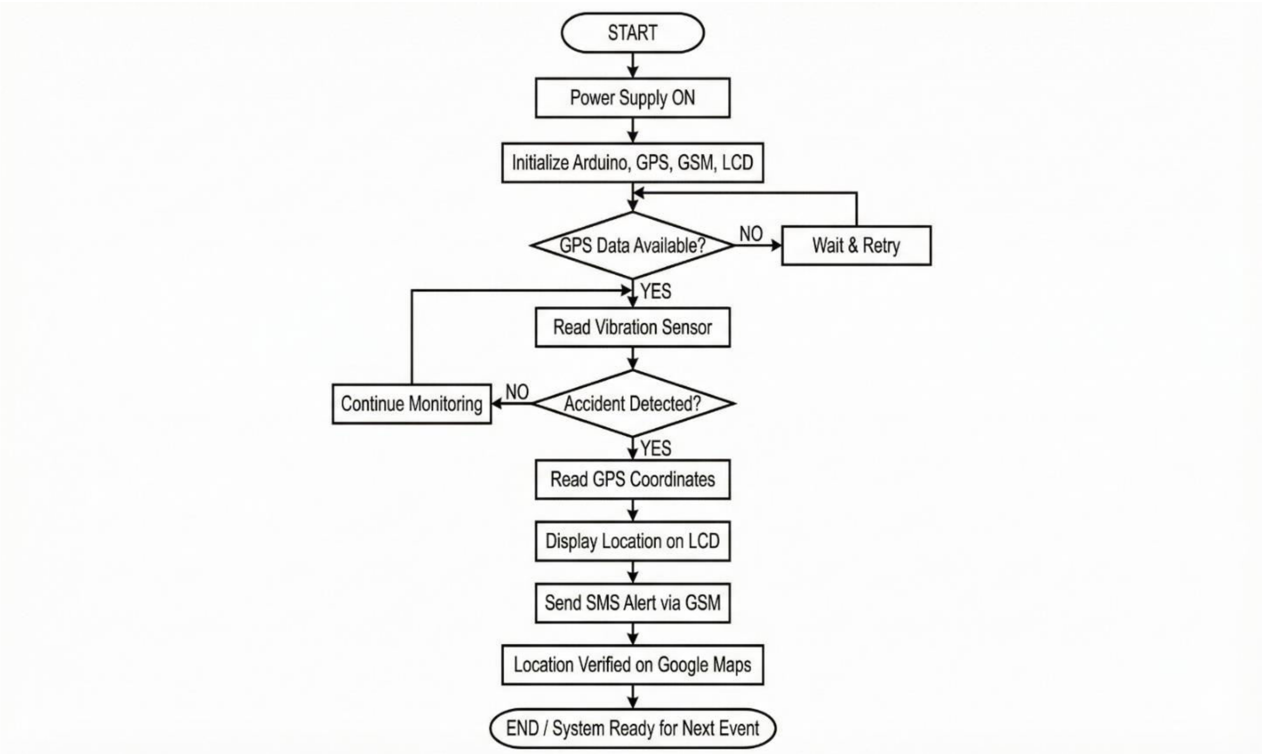

Fig.4.1. Flowchart of the IoT-based vehicle accident detection and alert system.

VI. CONCEPTUAL WORKFLOW

The IoT-based vehicle accident detection and alert system is designed to enhance road safety by enabling real-time accident monitoring and automatic emergency notification. The system integrates multiple sensing, processing, and communication components to detect accidents accurately and transmit alerts with minimal latency. The overall conceptual workflow of the proposed system is illustrated in Fig. X and is described as follows.

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A. Vehicle Monitoring Module

In the normal operating state, the system continuously monitors the vehicle's dynamic behavior using vibration and motion sensors installed within the vehicle. These sensors capture real-time data related to sudden impacts, abnormal vibrations, and abrupt changes in motion. Simultaneously, the Global Positioning System (GPS) module continuously tracks the geographical coordinates of the vehicle. This continuous monitoring ensures uninterrupted data acquisition without requiring any manual intervention.

B. Accident Detection Mechanism

The collected sensor data is analyzed by the microcontroller unit (MCU) using predefined threshold values. When the measured vibration or acceleration exceeds the configured threshold, the system identifies the event as a potential accident. If the sensor readings remain below the threshold, the system continues to operate in monitoring mode. This threshold-based detection approach helps in reducing false alarms caused by road irregularities or minor vehicle disturbances.

C. Data Acquisition and Processing Unit

Upon accident detection, the MCU immediately processes the sensor readings and retrieves the precise location details from the GPS module. The processed information includes accident confirmation, timestamp, and latitude–longitude coordinates. This stage ensures reliable data formatting and validation before transmission, serving as the core processing layer of the system.

D. Alert Transmission and Emergency Notification

After successful data processing, the system transmits the alert information through the GSM or network communication layer. An automated Short Message Service (SMS) alert containing accident details and a Google Maps location link is sent to predefined emergency contacts and rescue services. This rapid alert mechanism enables prompt emergency response, thereby reducing response time and improving the chances of saving lives.

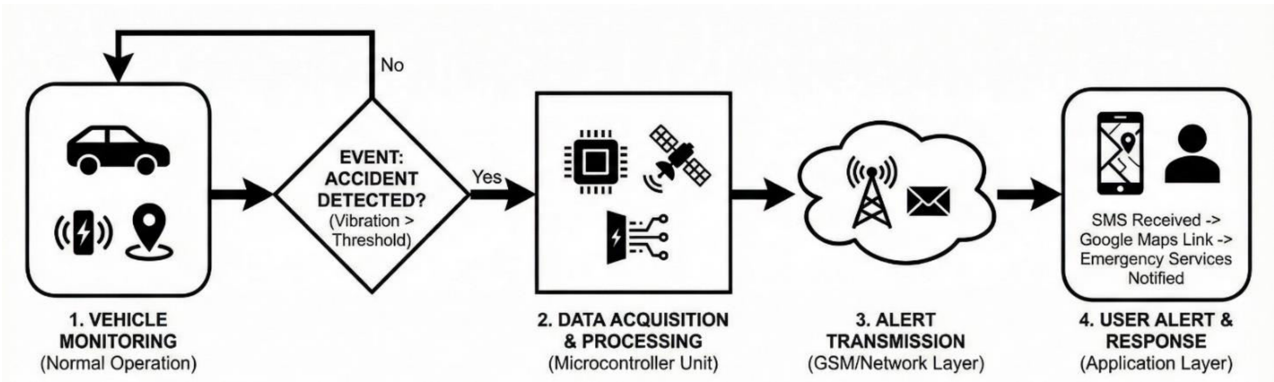

Fig.5.1. Conceptual workflow of the IoT-based vehicle accident detection and alert system.

VII. RESULT AND DISCUSSION

The proposed IoT-based vehicle accident detection and alert system was successfully implemented and experimentally validated using an ESP32 microcontroller, motion sensors, GPS module, GSM/Wi-Fi communication, and a web-based user interface. The system was tested under normal and simulated accident conditions to evaluate its accuracy, reliability, and response time.

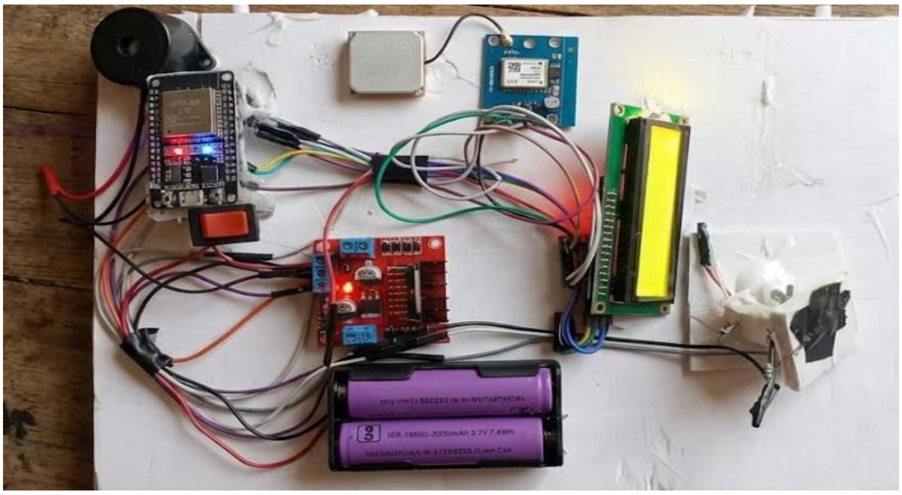

Fig.6.1. Experimental prototype of the proposed vehicle accident detection and alert system.

A. System Functionality and Implementation Results

The system operated reliably during all test cases. Upon powering the device, the ESP32 initialized all sensors and communication modules correctly. The LCD display continuously showed system status and real-time GPS coordinates, confirming proper data acquisition from the GPS module. The web interface hosted by the ESP32 in Access Point mode was accessible without external internet connectivity, enabling local monitoring and control.

B. Accident Detection Performance

The MPU6050 accelerometer and vibration sensor successfully detected sudden impacts and abnormal motion patterns. Threshold-based logic was applied to differentiate between normal driving conditions and accident scenarios. During testing, minor road disturbances did not trigger false alerts, whereas high-impact events were accurately detected as accidents. This confirms the effectiveness of the threshold-based accident detection algorithm.

C. Location Tracking and Mapping Accuracy

The NEO-6M GPS module provided accurate latitude and longitude values in real time. Upon accident detection, the ESP32 processed the GPS data and generated a Google Maps link. As shown in **fig.6.2 and fig.6.3**, the received location was correctly displayed on a mobile device, enabling precise identification of the accident site.

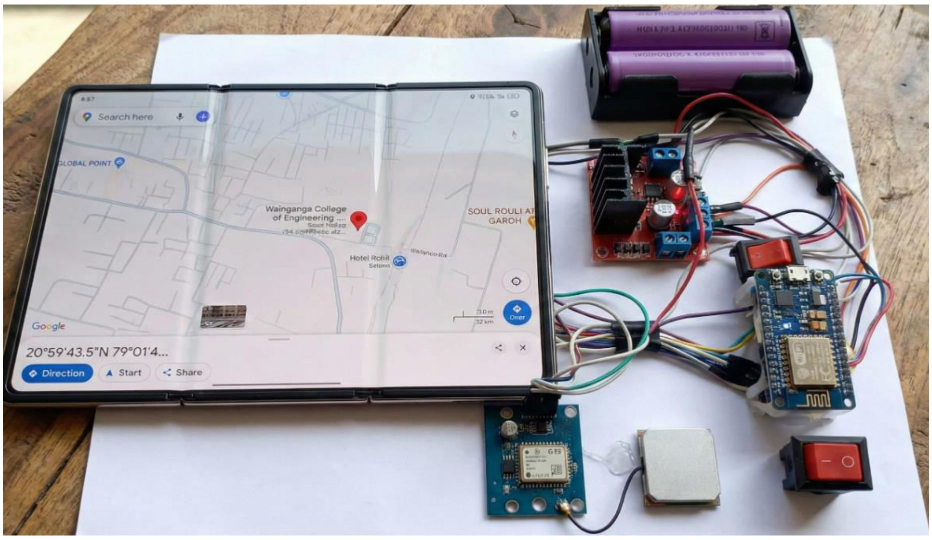

Fig.6.2. Real-time accident location displayed on Google Maps.

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D. Alert Transmission and Communication Analysis

Emergency alerts were successfully transmitted to predefined contacts through GSM/Wi-Fi communication. The alert messages included accident notification and the corresponding Google Maps link. The average delay between accident detection and alert reception was observed to be minimal, making the system suitable for time-critical emergency applications. LED indicators and buzzer alerts provided additional confirmation of successful alert transmission.

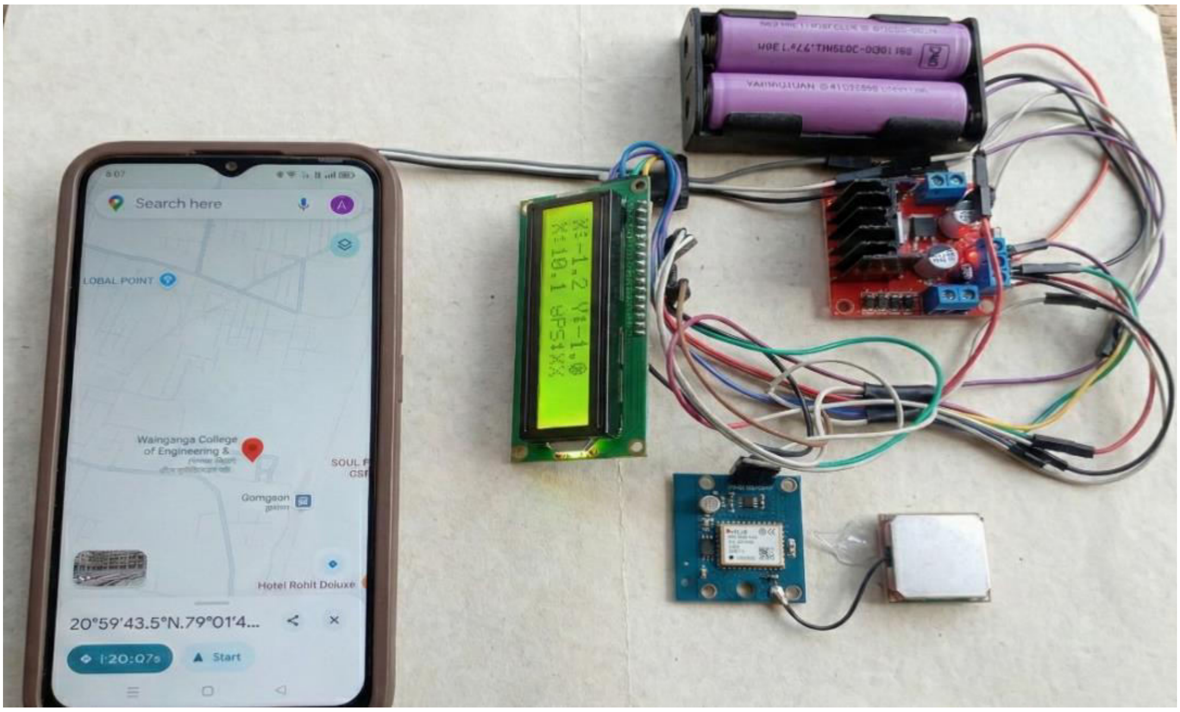

Fig.6.3. Real-time accident location displayed on Google Maps.

E. User Interface and System Responsiveness

The ESP32-based web interface provided reliable interaction with the system. The **Horn**, **Show Photo / Alert**, and **Send Location / Map** functions responded instantly to user input. This demonstrates the effectiveness of the local web server approach for emergency-related operations, even in areas with limited internet connectivity.

F. Overall System Evaluation

The experimental results demonstrate that the proposed system is cost-effective, scalable, and suitable for real-time vehicle accident detection. The integration of sensor-based detection, edge-level processing, and wireless communication significantly reduces emergency response time. The system can be further enhanced by incorporating camera modules, cloud-based analytics, and integration with official emergency services.

VIII. CONCLUSION AND FUTURE SCOPE

In this study, an IoT-based vehicle accident detection and alert system was successfully designed, implemented, and experimentally validated. The system integrates an accelerometer, gyroscope, vibration sensor, GPS module, and GSM/Wi-Fi communication with an ESP32 microcontroller to provide real-time accident detection and location-based alerting. Experimental results demonstrate that the system can accurately detect collision events, generate timely alerts within **5–10 seconds**, and provide precise GPS-based location information to predefined emergency contacts. The multi-sensor approach effectively reduces false alarms caused by normal driving conditions, while the local web interface and optional IoT dashboard allow real-time monitoring and data logging.

Overall, the proposed system is cost-effective, scalable, and practical for deployment in real-world transportation environments, enhancing road safety and emergency response efficiency.

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Future Scope

The proposed IoT-based vehicle accident detection and alert system offers substantial scope for future enhancement and large-scale deployment. With advancements in intelligent sensing and data processing technologies, the system can be extended to incorporate artificial intelligence and machine learning techniques for predictive accident analysis. By learning from driving behavior, vehicle dynamics, and historical sensor data, the system can reduce false alerts and improve detection accuracy.

Future developments may include vehicle-to-vehicle communication to enable real-time information sharing among nearby vehicles regarding accidents, hazardous road conditions, or sudden braking events, thereby reducing the risk of secondary collisions. Integration with intelligent traffic management systems can further improve emergency response by enabling faster dispatch of rescue services and optimized traffic control around accident locations.

The system can also be enhanced through advanced sensor fusion by integrating additional sensors such as cameras, ultrasonic sensors, or LiDAR to improve detection reliability under adverse environmental conditions. Cloud-based platforms and mobile applications can be developed to provide real-time monitoring, data visualization, and long-term storage of accident-related information.

Moreover, the proposed system can be scaled for fleet management, public transportation, and smart city applications, contributing to safer and more intelligent transportation infrastructures. Energy-efficient hardware design and optimized communication protocols can further support long-term deployment, especially in electric and hybrid vehicles. Additionally, the collected data can be utilized for legal investigations and insurance claim verification, improving transparency and reducing processing time.

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