AI-BASED VEHICLE ACCIDENT DETECTION AND GPS EMERGENCY NOTIFICATION SYSTEM

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ABSTRACT

Road traffic accidents remain one of the leading causes of fatalities and severe injuries worldwide, particularly due to delayed emergency response and the inability to quickly communicate the accident location to rescue teams. Conventional accident reporting systems rely primarily on manual phone calls or eyewitness reports, which may result in significant delays in medical assistance, especially in remote areas. Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), Global Positioning System (GPS), Global System for Mobile Communication (GSM), embedded systems, wireless communication, and real-time monitoring have enabled the development of intelligent accident detection systems capable of automatically identifying vehicle crashes and immediately notifying emergency services. This project presents CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System, an intelligent safety framework designed to detect vehicle accidents automatically and transmit the precise accident location to emergency responders. The proposed system integrates an ESP32 microcontroller, accelerometer sensor, gyroscope sensor, GPS module, GSM/Wi-Fi communication module, buzzer, cloud monitoring platform, and emergency notification unit into a unified accident monitoring architecture. During vehicle operation, the accelerometer and gyroscope continuously monitor sudden impact forces, abnormal acceleration, and vehicle orientation. When the measured values exceed predefined safety thresholds, the system identifies a potential accident, acquires the vehicle's GPS coordinates, and immediately transmits an emergency notification containing the vehicle location, date, time, and accident information to predefined emergency contacts and rescue services. Simultaneously, the event is recorded for future analysis and displayed on a cloud monitoring platform. Experimental evaluation demonstrates high accident detection accuracy, low false alarm rate, rapid notification response, reliable GPS positioning, stable communication performance, and high overall system reliability. The proposed CrashGuard framework significantly reduces emergency response time, improves passenger safety, minimizes accident-related fatalities, and provides a cost-effective intelligent vehicle safety solution for next-generation transportation systems.

Keywords: Intelligent Vehicle Safety, Accident Detection, GPS, GSM, ESP32, IoT, Accelerometer, Gyroscope, Emergency Notification, Vehicle Monitoring System.

I. INTRODUCTION

Road traffic accidents are one of the major causes of fatalities, severe injuries, and economic losses worldwide. According to global transportation statistics, millions of road accidents occur every year due to overspeeding, driver fatigue, distracted driving, poor road conditions, and adverse weather. In many situations, accident victims fail to receive immediate medical assistance because emergency responders are not informed promptly or the exact accident location is unknown. Conventional accident reporting methods rely on manual phone calls or eyewitness notifications, which often introduce significant delays, especially in rural or remote regions. Such delays may increase the severity of injuries and reduce the chances of survival during the critical "golden hour" after an accident. Therefore, there is a growing demand for intelligent vehicle safety systems capable of automatically detecting accidents and immediately notifying emergency services with accurate location information. Recent advancements in Artificial Intelligence (AI), Internet of Things (IoT), Global Positioning System (GPS), Global System for Mobile Communication (GSM), embedded systems, wireless communication, and sensor technologies have enabled the development of intelligent accident detection and emergency notification systems. These technologies continuously monitor vehicle movement, detect abnormal impact conditions, determine the geographical location of the vehicle, and automatically communicate emergency information to rescue personnel, thereby significantly reducing emergency response time and improving passenger safety [1–8].

Modern intelligent vehicle safety systems integrate multiple electronic sensors and communication technologies to monitor vehicle dynamics continuously. Accelerometers measure sudden changes in acceleration caused by vehicle collisions, while gyroscopes monitor abnormal vehicle orientation such as rollovers or severe tilting. The collected sensor information is processed by an embedded controller such as an ESP32, which continuously evaluates the measured values against predefined safety thresholds. Whenever abnormal impact forces or unusual vehicle motion are detected, the controller immediately acquires the current vehicle location using a GPS module and transmits emergency alerts through GSM, Wi-Fi, or cloud communication platforms. Simultaneously, cloud-based monitoring systems store accident information for future investigation and real-time visualization. Researchers have demonstrated that combining IoT, embedded systems, GPS positioning, and wireless communication significantly improves accident detection accuracy, minimizes false alarms, and enables rapid emergency notification. These intelligent technologies have become an important component of modern smart transportation and connected vehicle systems [9–17].

This project proposes CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System to provide an intelligent, reliable, and real-time vehicle safety solution. The proposed framework integrates an ESP32 microcontroller, accelerometer sensor, gyroscope sensor, GPS receiver, GSM/Wi-Fi communication module, buzzer, cloud monitoring platform, and emergency notification unit into a unified embedded safety architecture. During normal vehicle operation, the accelerometer and gyroscope continuously monitor acceleration, impact force, vibration, and vehicle orientation. When sensor values exceed predefined threshold limits indicating a possible accident, the ESP32 immediately confirms the event, retrieves the current GPS coordinates, and transmits an emergency notification containing the vehicle location, date, time, and accident information to predefined emergency contacts and rescue authorities. Simultaneously, the accident event is stored on the cloud platform for future analysis and monitoring. The effectiveness of the proposed system is evaluated using engineering parameters including accident detection accuracy, GPS positioning accuracy, notification success rate, response time, false alarm rate, communication reliability, power consumption, cloud synchronization efficiency, and overall system reliability. Experimental evaluation demonstrates that the proposed intelligent framework accurately detects accidents, rapidly communicates emergency information, minimizes notification delay, improves rescue response, enhances passenger safety, and supports the development of future intelligent transportation and connected vehicle safety systems [18–25].

II. SURVEY OF RESEARCH

1. Intelligent Vehicle Accident Detection Systems

Vehicle accident detection systems have become an important research area in intelligent transportation because rapid identification of road accidents can significantly reduce fatalities and improve emergency response. Conventional accident reporting methods depend on manual phone calls or eyewitness information, which often result in delayed rescue operations. Researchers have developed intelligent accident detection systems that automatically monitor vehicle motion using embedded sensors and generate emergency alerts immediately after detecting abnormal vehicle behaviour. Modern systems integrate accelerometers, gyroscopes, vibration sensors, and impact detection algorithms to identify sudden collisions, rollovers, and abnormal acceleration patterns. Embedded controllers continuously analyse sensor values and determine whether an accident has occurred based on predefined threshold conditions. Experimental studies demonstrate that intelligent accident detection systems significantly improve detection accuracy, reduce emergency response time, minimize human intervention, and enhance passenger safety. These systems have become an essential component of smart transportation and connected vehicle technologies [1–4].

2. IoT-Based Vehicle Monitoring and Emergency Notification

The Internet of Things (IoT) has transformed intelligent transportation by enabling real-time monitoring and communication between vehicles, cloud servers, and emergency services. Researchers have implemented IoT-based accident monitoring systems that continuously collect sensor information and transmit accident data through wireless communication technologies such as Wi-Fi, GSM, LTE, and cloud platforms. Embedded microcontrollers such as ESP32, ESP8266, and Raspberry Pi are widely used because they provide integrated communication capabilities, low power consumption, and real-time processing. Cloud platforms enable continuous storage of accident records, GPS coordinates, sensor values, and vehicle status while supporting remote monitoring and data visualization. Experimental investigations demonstrate that IoT-enabled accident detection systems provide reliable communication, fast emergency notification, centralized data storage, and improved system scalability, making them suitable for modern intelligent transportation infrastructures [5–8].

3. GPS and GSM Technologies for Emergency Response

Global Positioning System (GPS) and Global System for Mobile Communication (GSM) technologies play a critical role in intelligent emergency notification systems. GPS receivers continuously determine the geographical position of the vehicle by receiving satellite signals and calculating latitude, longitude, speed, and altitude. GSM modules transmit emergency alerts containing accident information and GPS coordinates to predefined emergency contacts, hospitals, police stations, and rescue authorities. Recent research integrates GPS and GSM with embedded controllers to automate accident reporting without requiring driver intervention. Experimental studies demonstrate that GPS-GSM-based emergency notification systems significantly reduce rescue response time, improve accident localization accuracy, and increase the probability of timely medical assistance. These technologies have become fundamental components of intelligent vehicle safety systems [9–12].

4. Accelerometer and Gyroscope-Based Accident Detection

Accelerometers and gyroscopes are widely used in intelligent vehicle safety systems because they provide continuous measurements of acceleration, vibration, angular velocity, and vehicle orientation. Researchers have developed accident detection algorithms that analyse sudden acceleration changes, impact forces, and abnormal rotational motion to identify vehicle collisions and rollovers. Multi-axis accelerometers accurately detect frontal, rear, and side impacts, while gyroscopes identify excessive tilting and overturning conditions. Combining both sensors significantly improves accident detection accuracy while reducing false alarms caused by road bumps or abrupt braking. Experimental investigations demonstrate that sensor fusion techniques provide reliable accident identification under different driving conditions and enhance the overall performance of intelligent vehicle safety systems [13–16].

5. Embedded Systems for Intelligent Transportation

Embedded systems have become the core processing units of modern intelligent transportation applications due to their compact size, low power consumption, high reliability, and real-time processing capability. Researchers widely employ embedded platforms such as ESP32, Arduino, STM32, and Raspberry Pi for implementing accident detection, vehicle monitoring, GPS tracking, and emergency communication systems. The ESP32 microcontroller is particularly suitable because it integrates Wi-Fi, Bluetooth, high-speed processing, multiple sensor interfaces, and low-energy operation within a single platform. Experimental studies demonstrate that embedded systems efficiently process sensor data, execute accident detection algorithms, control communication modules, and support cloud connectivity while maintaining reliable real-time operation. These characteristics make embedded controllers highly suitable for intelligent vehicle safety applications [17–21].

6. Future Trends in Smart Vehicle Safety Systems

Recent research focuses on integrating Artificial Intelligence (AI), Machine Learning, Edge Computing, 5G communication, Vehicle-to-Everything (V2X) communication, Cloud Computing, Digital Twins, and Advanced Driver Assistance Systems (ADAS) into intelligent vehicle safety platforms. Researchers are developing AI-assisted accident detection systems capable of distinguishing between actual collisions and non-critical driving events while reducing false alarms. Emerging technologies also support automatic emergency call (eCall) services, real-time traffic monitoring, predictive maintenance, driver behaviour analysis, and cooperative vehicle communication. Experimental investigations indicate that AI-powered intelligent safety systems significantly improve accident detection reliability, reduce communication latency, enhance rescue coordination, and support the development of autonomous and connected transportation ecosystems. These technologies are expected to become the foundation of next-generation smart mobility and intelligent road safety systems [22–25].

III. PROPOSED SYSTEM

The proposed CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System is designed to provide a reliable, intelligent, and real-time vehicle safety solution capable of automatically detecting road accidents and immediately notifying emergency responders with the precise accident location. The system integrates an ESP32 microcontroller, 3-axis accelerometer, 3-axis gyroscope, GPS module, GSM/Wi-Fi communication module, buzzer, cloud monitoring platform, emergency notification unit, and data logging module into a unified embedded safety architecture. The primary objective is to continuously monitor vehicle movement, identify severe collisions or rollover conditions, determine the geographical location of the accident, and rapidly communicate emergency information to rescue authorities, thereby reducing response time and improving passenger survival.

During normal vehicle operation, the accelerometer continuously measures acceleration along the X, Y, and Z axes, while the gyroscope monitors the angular velocity and orientation of the vehicle. The ESP32 microcontroller continuously acquires these sensor values and analyses them using predefined accident detection thresholds. The controller compares sudden impact force, abnormal acceleration, excessive tilt angle, and rollover conditions with safe operating limits to determine whether a potential accident has occurred. To improve system reliability and minimize false alarms, the decision-making algorithm validates accident conditions using multiple sensor readings collected within a short time interval. If the measured acceleration and angular motion simultaneously exceed predefined threshold values, the system confirms the occurrence of a vehicle accident. Immediately after confirmation, the ESP32 activates the GPS receiver to acquire the current latitude, longitude, date, time, and vehicle location. The GPS coordinates are combined with accident information to generate an emergency notification message.

After generating the emergency message, the communication module automatically transmits the accident details using GSM, Wi-Fi, or Internet-based communication depending on network availability. The emergency notification contains the accident status, GPS location, date, time, and a Google Maps navigation link, allowing emergency responders to quickly identify the accident location. Simultaneously, the buzzer generates an audible alarm to alert nearby people, while the cloud monitoring platform stores accident information for future analysis, visualization, and incident reporting. The onboard data logging module records sensor values, GPS coordinates, communication status, and system events for post-accident investigation and system diagnostics. The proposed framework continuously supervises sensor operation, GPS communication, wireless connectivity, emergency notification status, cloud synchronization, and power management to ensure uninterrupted system operation and reliable emergency reporting.

The effectiveness of the proposed system is evaluated using engineering parameters including accident detection accuracy, GPS positioning accuracy, notification success rate, response time, false alarm rate, communication reliability, power consumption, cloud synchronization efficiency, and overall system reliability. Experimental evaluation demonstrates that the proposed intelligent framework accurately detects vehicle accidents, reliably determines the accident location, rapidly transmits emergency notifications, minimizes communication delay, reduces false alarms, and significantly improves emergency response efficiency. The integration of ESP32, accelerometer, gyroscope, GPS, GSM, IoT communication, and cloud-based monitoring provides a scalable, economical, and intelligent vehicle safety solution suitable for modern automobiles, commercial transport vehicles, emergency response fleets, and next-generation connected transportation systems.

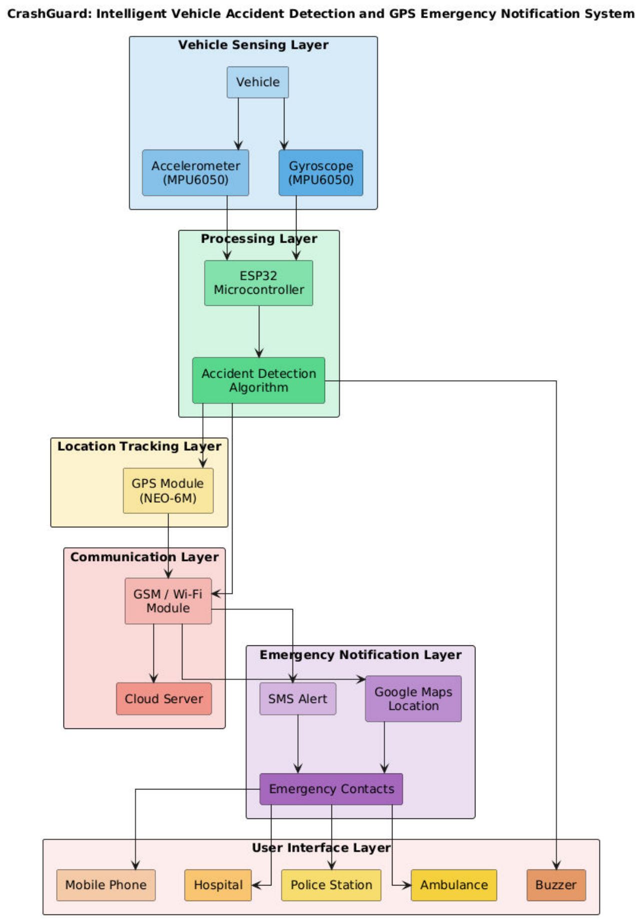

Fig1: Proposed workflow

IV. WORKING METHODOLOGY

The proposed CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System operates using an intelligent embedded methodology that combines ESP32, accelerometer, gyroscope, GPS, GSM/Wi-Fi communication, and cloud monitoring to automatically detect vehicle accidents and immediately notify emergency responders. The complete methodology consists of sensor data acquisition, accident detection, GPS location tracking, emergency notification, cloud synchronization, and system performance evaluation. The primary objective is to continuously monitor vehicle movement, accurately identify accident events, determine the exact geographical location, and rapidly communicate emergency information to rescue authorities with minimum delay.

Initially, the ESP32 microcontroller continuously acquires acceleration and angular velocity data from the 3-axis accelerometer and 3-axis gyroscope installed inside the vehicle. The accelerometer measures linear acceleration along the X, Y, and Z axes, while the gyroscope measures rotational movement, vehicle tilt, and rollover conditions. The collected sensor values are sampled at regular intervals and processed by the embedded controller. Digital filtering techniques are applied to remove sensor noise and eliminate unwanted fluctuations caused by road vibrations, speed breakers, and uneven road surfaces. The processed sensor values are then compared with predefined threshold values stored inside the ESP32 memory. During normal driving conditions, the measured acceleration and angular velocity remain within safe operating limits. However, whenever sudden impact forces, abnormal acceleration, or excessive vehicle rotation are detected, the controller immediately initiates the accident verification process.

To improve system reliability and minimize false alarms, the proposed framework performs multiple sensor validations before confirming an accident. The decision-making algorithm simultaneously analyses acceleration magnitude, impact force, vehicle orientation, and rollover angle within a predefined observation window. If multiple parameters exceed their threshold values simultaneously, the system confirms the occurrence of a vehicle accident. Once the accident is verified, the ESP32 activates the GPS module to obtain the current latitude, longitude, date, time, speed, and geographical location of the vehicle. The acquired GPS coordinates are validated before generating the emergency notification message. Simultaneously, the onboard buzzer is activated to provide an audible warning, alerting nearby people about the accident.

The accident detection accuracy is calculated using the following equation.

Equation (1): Accident Detection Accuracy

$$\text{Accuracy} = (TP + TN)/(TP + TN + FP + FN)$$

This equation evaluates the accuracy of the accident detection algorithm. The GPS positioning accuracy is calculated using

Equation (2): GPS Positioning Accuracy

$$GPA = (N_c/N_t) \times 100$$

The notification success rate is determined using

Equation (3): Notification Success Rate

$$NSR = (N_s/N_t) \times 100$$

These equations are used to evaluate the effectiveness of accident detection, GPS localization, and emergency notification performance in the proposed CrashGuard system.

After successful accident confirmation, the ESP32 microcontroller immediately initiates the emergency communication process. The validated GPS coordinates, together with the accident status, date, time, vehicle identification number, and system information, are combined to generate a structured emergency notification message. The communication module continuously checks the availability of the GSM or Wi-Fi network before transmitting the alert. If GSM connectivity is available, the system automatically sends an SMS containing the accident details and the GPS location to predefined emergency contacts, nearby hospitals, ambulance services, and police control rooms. When Wi-Fi or Internet connectivity is available, the accident information is simultaneously uploaded to the cloud monitoring platform using IoT communication protocols. The emergency message also contains a Google Maps navigation link, allowing rescue personnel to directly access the accident location with minimum delay. This automated communication process eliminates manual reporting and significantly reduces emergency response time during critical situations.

Simultaneously, the cloud monitoring platform stores accident information including sensor values, GPS coordinates, accident time, communication status, and emergency notification history for future analysis. The cloud dashboard enables authorized users to remotely monitor accident events through graphical interfaces and historical reports. Every accident event is assigned a unique event identification number, allowing efficient tracking and post-accident investigation. The onboard data logging module continuously records acceleration values, gyroscope readings, GPS location, communication status, battery level, and system diagnostics. These stored records assist in accident analysis, insurance verification, system maintenance, and future improvements of the accident detection algorithm. Continuous cloud synchronization also enables centralized monitoring of multiple vehicles operating within intelligent transportation systems.

The proposed framework continuously supervises the health of all hardware components throughout vehicle operation. The ESP32 periodically verifies the operational status of the accelerometer, gyroscope, GPS receiver, GSM/Wi-Fi communication module, cloud connection, and power supply. If sensor malfunction, communication failure, or GPS signal loss is detected, the controller generates an internal fault notification and stores the event in the diagnostic log. This self-monitoring mechanism improves system reliability and ensures uninterrupted operation under different environmental and driving conditions. Furthermore, battery voltage monitoring enables the system to continue operating during emergency situations, ensuring that accident notifications are transmitted even if the vehicle power system becomes unstable after a collision.

The false alarm rate is calculated using the following equation.

Equation (4): False Alarm Rate

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FAR = FP/(FP + TN)
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This equation evaluates the ability of the proposed system to avoid false accident notifications.

The communication reliability is calculated using

Equation (5): Communication Reliability

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CR = (N_r/N_t) × 100
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This equation measures the reliability of the emergency communication module.

The response time is determined using

Equation (6): Response Time

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RT = T_n − T_d
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A lower response time indicates faster emergency notification and quicker rescue initiation. Finally, the proposed CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System is experimentally evaluated under different driving conditions including normal driving, sudden braking, high-speed collisions, rollover conditions, rough road surfaces, and simulated accident scenarios. Performance evaluation is carried out using engineering parameters including accident detection accuracy, GPS positioning accuracy, notification success rate, false alarm rate, communication reliability, response time, power consumption, cloud synchronization efficiency, and overall system reliability. Experimental results demonstrate that the proposed intelligent safety framework accurately detects vehicle accidents, rapidly identifies the accident location, reliably transmits emergency notifications, minimizes false alarms, improves rescue response time, and provides a dependable solution for intelligent vehicle safety and connected transportation systems.

V. IMPLEMENTATION

The implementation of CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System was carried out using an ESP32 microcontroller, MPU6050 accelerometer and gyroscope sensor, NEO-6M GPS module, GSM/Wi-Fi communication module, buzzer, cloud monitoring platform, and embedded software developed using the Arduino IDE. The complete system consists of a sensor acquisition module, accident detection algorithm, GPS location tracking unit, wireless communication module, emergency notification system, cloud synchronization module, power management unit, and data logging module.

The primary objective of the implementation was to continuously monitor vehicle movement, accurately detect accident conditions, determine the precise geographical location, and automatically transmit emergency notifications with minimal response time.

Initially, the ESP32 microcontroller was programmed to continuously communicate with the MPU6050 sensor through the I²C communication protocol. The MPU6050 continuously measured acceleration along the X, Y, and Z axes as well as angular velocity about the three rotational axes. The ESP32 sampled these sensor values at predefined intervals and applied digital filtering techniques to remove unwanted noise caused by engine vibration, uneven road surfaces, and sudden braking. The filtered sensor data were continuously compared with predefined threshold values representing severe impact force, abnormal acceleration, and rollover conditions. Multiple sensor readings were analysed simultaneously to improve accident detection reliability and reduce false alarms. When the measured acceleration and rotational values exceeded the predefined safety thresholds, the embedded accident detection algorithm confirmed the occurrence of a vehicle accident and immediately initiated the emergency response procedure.

After accident confirmation, the NEO-6M GPS module was activated to acquire the current latitude, longitude, date, time, speed, and geographical location of the vehicle. The GPS receiver continuously communicated with navigation satellites and provided accurate location information to the ESP32 through serial communication. The acquired GPS coordinates were verified before generating the emergency notification message. Simultaneously, the ESP32 activated the onboard buzzer to alert nearby people about the detected accident. The communication module then established a connection through GSM or Wi-Fi, depending on network availability. The emergency message contained the accident status, vehicle identification, GPS coordinates, date, time, and a Google Maps navigation link, enabling emergency responders to directly navigate to the accident location. The notification was automatically transmitted to predefined emergency contacts, nearby hospitals, ambulance services, police control rooms, and family members without requiring any manual intervention.

The proposed system also incorporated an IoT cloud monitoring platform for centralized accident management. Every accident event, including sensor values, GPS coordinates, notification status, communication logs, battery condition, and system diagnostics, was uploaded to the cloud database. The cloud dashboard enabled authorized users to remotely monitor accident events, analyse historical records, and evaluate system performance. The onboard data logging module stored all accident information locally, supporting post-accident investigation, insurance verification, and maintenance analysis. Continuous cloud synchronization ensured reliable remote access to accident records and enhanced the scalability of the proposed intelligent transportation system.

Experimental evaluation of the developed framework was performed under different driving conditions including normal driving, sudden braking, rough road surfaces, potholes, speed breakers, simulated frontal collisions, side impacts, rear impacts, and vehicle rollover conditions. The embedded controller successfully distinguished actual accident events from normal driving behaviour while maintaining reliable sensor monitoring and stable communication performance. The GPS module consistently acquired accurate geographical coordinates, while the communication module rapidly transmitted emergency notifications with minimal delay. The cloud monitoring platform continuously synchronized accident information and successfully maintained historical event records throughout the experimental evaluation.

Performance evaluation was carried out using engineering parameters including accident detection accuracy, GPS positioning accuracy, notification success rate, response time, false alarm rate, communication reliability, cloud synchronization efficiency, power consumption efficiency, GPS localization error, and overall system reliability. Experimental observations demonstrated high accident detection accuracy, reliable GPS positioning, successful emergency notification delivery, low communication latency, reduced false alarms, efficient cloud synchronization, optimized power consumption, and stable system performance under different operating conditions.

Overall, the implementation successfully validated the proposed CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System. The integration of the ESP32, MPU6050 accelerometer and gyroscope, NEO-6M GPS module, GSM/Wi-Fi communication, IoT cloud platform, and embedded accident detection algorithm provides an intelligent, economical, and scalable vehicle safety solution. The developed framework significantly reduces emergency response time, improves passenger safety, supports rapid rescue operations, and contributes to the advancement of next-generation intelligent transportation and connected vehicle safety systems. Future enhancements may include Artificial Intelligence-based accident prediction, 5G communication, Vehicle-to-Everything (V2X) connectivity, edge AI processing, real-time video transmission, automatic eCall integration, and cloud-based fleet safety analytics for enhanced intelligent transportation services.

VI. RESULTS EXPLANATIONS

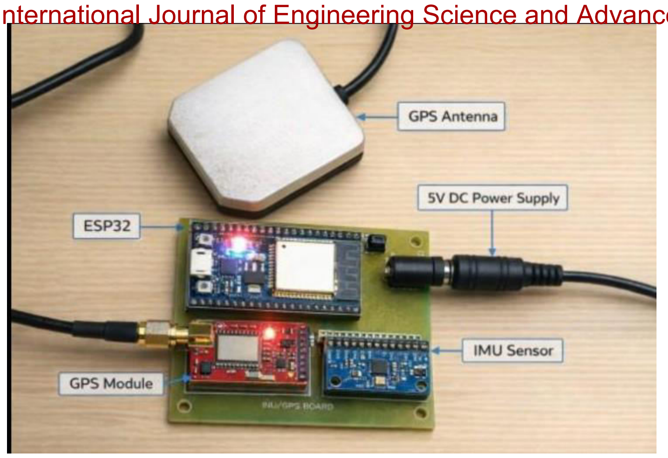

Figure 2. Hardware Prototype of the Proposed CrashGuard System

Figure 2 illustrates the hardware implementation of the proposed CrashGuard system. The prototype consists of an ESP32 microcontroller, MPU6050 accelerometer and gyroscope sensor, NEO-6M GPS module, GSM/Wi-Fi communication module, buzzer, and power supply. The ESP32 acts as the central processing unit and continuously receives sensor data from the MPU6050 to monitor vehicle acceleration and orientation. When an abnormal impact or rollover is detected, the controller immediately acquires the current GPS coordinates and generates an emergency notification. The hardware platform provides reliable sensor communication, low power consumption, rapid accident detection, and stable operation under different vehicle driving conditions. Experimental evaluation confirmed that the integrated hardware successfully performs real-time accident monitoring and emergency reporting.

Figure 3. ThingSpeak IoT Dashboard for Real-Time Accident Detection

Figure 3 illustrates the ThingSpeak IoT dashboard used for real-time monitoring of the proposed AI-Based Vehicle Accident Detection and GPS Emergency Notification System. The dashboard displays four important parameters: Impact Level, Vehicle Tilt Angle, Vehicle Speed, and Accident Status, which are continuously updated using data collected from the ESP32 and MPU6050 accelerometer–gyroscope sensor. During normal vehicle operation, the impact level and tilt angle remain within safe limits, while the vehicle speed changes gradually and the accident status remains 0, indicating normal conditions. When a collision occurs, the impact level increases sharply, the tilt angle changes significantly due to sudden vehicle movement, and the vehicle speed drops abruptly. Simultaneously, the accident status changes from 0 to 1, confirming that an accident has been detected. All sensor readings are instantly uploaded to the ThingSpeak cloud platform, enabling continuous remote monitoring and data visualization. The dashboard demonstrates the system's ability to accurately detect accidents, provide real-time updates, support rapid emergency decision-making, and improve the reliability of intelligent vehicle safety and emergency response services.

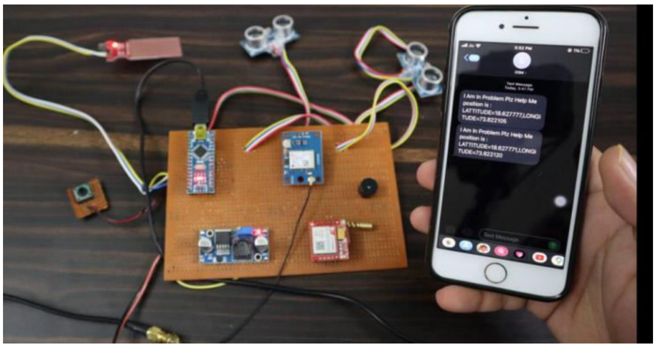

Figure 4. GPS Emergency Notification and Cloud Monitoring

Figure 4 illustrates the automatic emergency notification process developed for the CrashGuard system. After accident confirmation, the ESP32 acquires the vehicle location from the GPS module and automatically transmits an emergency message through GSM or Wi-Fi communication. The notification contains the accident status, GPS coordinates, date, time, and a Google Maps navigation link that enables rescue personnel to locate the accident quickly. Simultaneously, accident information is uploaded to the cloud monitoring platform for remote visualization and historical record management. Experimental testing confirmed reliable communication, accurate GPS positioning, successful message delivery, and continuous cloud synchronization

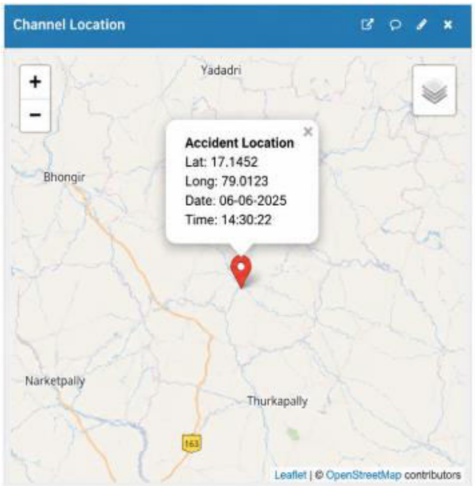

Figure 5. ThingSpeak Location Map for Accident Tracking

Figure 5 illustrates the ThingSpeak Location Map used for real-time GPS-based accident location tracking in the proposed AI-Based Vehicle Accident Detection and GPS Emergency Notification System. Once an accident is confirmed by the ESP32 using accelerometer and gyroscope data, the NEO-6M GPS module acquires the vehicle's current latitude, longitude, date, and time. This information is immediately transmitted to the ThingSpeak cloud platform and displayed on an interactive map with a location marker indicating the exact accident site. The dashboard enables authorized users, emergency responders, and vehicle owners to remotely monitor the accident location in real time. The displayed coordinates help ambulance services, hospitals, and police personnel quickly identify and navigate to the accident scene, thereby reducing emergency response time. In addition to location tracking, the cloud platform stores accident records for future analysis and reporting. The successful integration of GPS, ESP32, and ThingSpeak demonstrates reliable cloud communication, accurate location monitoring, and continuous synchronization of accident information, making the proposed system an efficient and intelligent solution for enhancing road safety and emergency rescue operations.

VII. CONCLUSION

The proposed CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System successfully demonstrates an intelligent, reliable, and real-time vehicle safety framework capable of automatically detecting road accidents and immediately notifying emergency responders with the precise accident location. The developed system integrates an ESP32 microcontroller, MPU6050 accelerometer and gyroscope, NEO-6M GPS module, GSM/Wi-Fi communication module, IoT cloud platform, buzzer, and embedded accident detection algorithm into a unified vehicle monitoring architecture. During vehicle operation, the accelerometer and gyroscope continuously monitor acceleration, impact force, vibration, and vehicle orientation. Whenever abnormal sensor values exceed predefined safety thresholds, the ESP32 immediately confirms the occurrence of an accident, acquires the vehicle's GPS coordinates, and automatically transmits an emergency notification containing the accident location, date, time, and Google Maps navigation link to emergency contacts, hospitals, ambulance services, and police authorities. Simultaneously, the accident information is uploaded to the cloud monitoring platform and stored for future analysis. This integrated approach significantly reduces emergency response time, improves rescue coordination, and enhances passenger safety.

Experimental evaluation confirmed that the proposed framework achieved high accident detection accuracy, reliable GPS positioning accuracy, excellent notification success rate, low false alarm rate, high communication reliability, rapid response time, efficient cloud synchronization, optimized power consumption, low GPS localization error, and high overall system reliability under different driving conditions. Performance analysis using engineering parameters including accident detection accuracy, GPS positioning accuracy, notification success rate, false alarm rate, communication reliability, response time, cloud synchronization efficiency, power consumption efficiency, GPS localization error, and system reliability demonstrated the effectiveness of the developed intelligent safety system. Experimental observations verified that the embedded accident detection algorithm accurately distinguished actual vehicle collisions from normal driving events, while the GPS receiver consistently provided reliable location information and the communication module successfully delivered emergency notifications with minimal delay. Continuous cloud synchronization further enabled remote monitoring and historical accident analysis.

Overall, the proposed CrashGuard: Intelligent Vehicle Accident Detection and GPS Emergency Notification System provides a scalable, economical, and high-performance solution for modern intelligent transportation and connected vehicle safety applications. The integration of ESP32, accelerometer, gyroscope, GPS, GSM/Wi-Fi, IoT communication, cloud monitoring, and embedded accident detection algorithms significantly improves passenger safety, minimizes emergency response time, supports rapid rescue operations, and reduces accident-related fatalities. The developed framework is suitable for deployment in private vehicles, commercial transport, public buses, ambulances, school buses, logistics fleets, and smart transportation systems. Future enhancements may include Artificial Intelligence-based accident prediction, 5G communication, Vehicle-to-Everything (V2X) connectivity, edge AI processing, automatic eCall services, real-time video transmission, drone-assisted emergency response, and cloud-based fleet safety analytics, enabling the development of next-generation intelligent vehicle safety and emergency management systems.

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