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IoT Based Collision Alert and Smart Accident Detection System

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Abstract: Road accidents continue to be a major cause of fatalities across the world, largely due to the delay in detecting accidents and the inability to communicate the victim's location to emergency responders in time. In many critical situations, accident victims are unconscious or physically unable to seek help, which significantly increases the risk of severe injury or death. To overcome this challenge, this paper presents the design and development of an IoT-based Accident Collision Detection and Safety Alert System using an ESP32 microcontroller integrated with GPS and GSM communication modules and multiple safety sensors. The proposed system automatically detects collisions using a limit switch–based impact sensor and immediately stops vehicle movement to prevent further damage. Once an accident is detected, the system sends emergency SMS alerts and initiates call notifications containing real-time GPS location information to predefined emergency contacts, ensuring rapid response. In addition to collision detection, the system includes ultrasonic sensors for obstacle detection, smoke sensors for identifying fire hazards, and a manual SOS push button that allows users to request emergency assistance during medical or critical situations. Distinct audio and visual alerts are generated using a buzzer and LED to indicate different emergency conditions. Furthermore, the ESP32 hosts a Wi-Fi-based web control interface that enables remote vehicle operation and manual override, enhancing system usability and flexibility. Experimental observations confirm reliable accident detection, accurate location tracking, and fast alert delivery, demonstrating that the proposed system is a low-cost, scalable, and effective solution for smart vehicles, autonomous platforms, and intelligent transportation systems, thereby significantly improving road safety and emergency response efficiency.

Keywords: Accident Collision Detection, Internet of Things (IoT), ESP32 Microcontroller, GPS Tracking, GSM Communication, Safety Alert System, Intelligent Transportation System

I. INTRODUCTION

Road transportation plays a vital role in modern society; however, it is also associated with a high risk of accidents that result in severe injuries, loss of life, and significant economic damage. Despite advancements in vehicle design and traffic regulations, road accidents continue to increase due to factors such as over-speeding, driver negligence, poor road conditions, and delayed emergency response. A major reason for the high fatality rate is the inability to detect accidents instantly and communicate accurate location information to emergency services in real time. In many cases, victims are unconscious or trapped inside the vehicle, making it impossible for them to seek help, which leads to delayed rescue operations and increased mortality.

With the rapid growth of the Internet of Things (IoT) and embedded systems, intelligent accident detection and alert mechanisms have become feasible and cost-effective. IoT enables real-time data collection, processing, and wireless communication, allowing safety systems to operate autonomously without human intervention. Microcontrollers such as the ESP32, equipped with built-in Wi-Fi, multiple communication interfaces, and high processing capability, provide an ideal platform for implementing smart safety applications. When combined with GPS for location tracking and GSM technology for emergency communication, IoT-based systems can significantly reduce emergency response time and improve survival rates.

In this context, the proposed IoT-based Accident Collision Detection and Safety Alert System aims to enhance vehicle safety by automatically identifying accident events and instantly notifying emergency contacts with precise location details. The system integrates multiple sensors, including a limit switch for collision detection, an ultrasonic sensor for obstacle monitoring, a smoke sensor for fire hazard detection, and a manual SOS button for user-initiated emergencies. Upon detecting a critical event, the system immediately stops vehicle movement, generates audio-visual alerts, and sends

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SMS and call notifications containing real-time GPS coordinates through a GSM module. Additionally, a Wi-Fi-based web control interface hosted on the ESP32 enables remote vehicle operation and manual override, improving system flexibility and usability.

The proposed system provides a comprehensive, low-cost, and scalable solution for real-time accident detection and emergency alerting, making it suitable for deployment in smart vehicles, autonomous platforms, and intelligent transportation systems. By reducing dependency on manual reporting and ensuring timely communication with emergency services, the system contributes significantly to improved road safety and efficient emergency management.

A. Motivation

Road accidents continue to be a major global concern, resulting in a large number of fatalities and serious injuries every year. A significant portion of these deaths occurs not only due to the severity of the accident but also because emergency assistance does not arrive on time. In many situations, accident victims are unable to communicate their condition or exact location due to unconsciousness, panic, or physical trauma. Traditional accident reporting systems rely heavily on manual intervention, which often leads to delayed response and loss of valuable time. Statistical analyses of accident data clearly indicate a steady increase in accident-related deaths, emphasizing the urgent need for intelligent systems that can automatically detect accidents and initiate emergency communication without relying on human action.

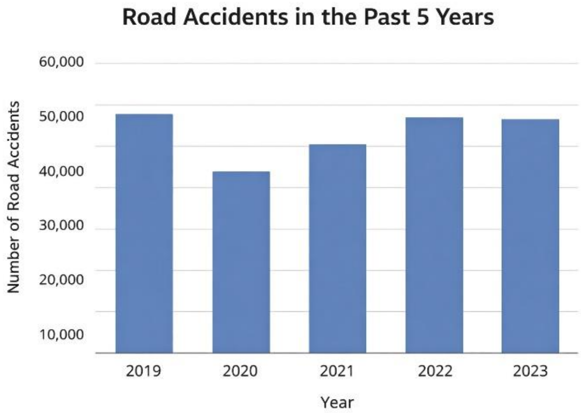

Fig 1: Visual representation of vehicle accidents that result in deaths per year

The motivation behind this work is to develop a low-cost, reliable, and automated safety system that can reduce emergency response time and improve survival chances after an accident. By leveraging IoT technologies such as the ESP32 microcontroller, GPS-based location tracking, GSM-based communication, and multiple safety sensors, the proposed system aims to ensure immediate detection of collision events and rapid transmission of critical information to emergency contacts. The inclusion of features such as manual SOS activation, obstacle detection, and fire hazard monitoring further strengthens the system's ability to handle real-world emergency scenarios. This approach not only enhances individual vehicle safety but also contributes to the broader vision of smart transportation systems and improved road safety infrastructure.

B. Research Contribution

This work presents a comprehensive IoT-based Accident Collision Detection and Safety Alert System that enhances vehicle safety by integrating multiple detection and communication mechanisms into a single, low-cost platform. Unlike many existing systems that focus only on accident detection or notification, the proposed system combines collision detection, obstacle monitoring, fire hazard identification, and manual emergency alerting to address a wide range of real-world accident scenarios. By employing an ESP32 microcontroller with GPS and GSM modules, the system ensures reliable real-time location tracking and immediate emergency communication through both SMS and call alerts, thereby reducing dependency on manual reporting and minimizing response delays.

A key contribution of this research lies in the use of **multi-sensor fusion**, including a limit switch for impact detection, ultrasonic sensors for obstacle detection, and smoke sensors for early fire identification. This approach improves detection accuracy and reduces false alarms when compared to single-sensor-based systems reported in earlier studies. Additionally, the inclusion of a **manual SOS push button** provides flexibility by allowing users to request emergency

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assistance during medical or critical situations even when a collision has not occurred, which is often not addressed in conventional accident detection systems.

Another significant contribution is the integration of a **Wi-Fi-based web control interface hosted on the ESP32**, enabling remote vehicle control and manual override. This feature enhances system usability and extends its applicability beyond traditional vehicles to autonomous robots and smart mobility platforms. The proposed system is designed to be scalable, cost-effective, and easy to deploy, making it suitable for intelligent transportation systems and smart city applications. Through experimental validation, this research demonstrates improved emergency response efficiency, reliable accident detection, and effective communication, contributing meaningfully to the advancement of IoT-based vehicular safety systems.

II. RELATED WORK

Pandey *et al.* presented an IoT-based collision alert system using Arduino and the Blynk platform to provide real-time accident detection and emergency notifications. The system employs ultrasonic and gyroscope sensors for collision detection, while GPS and GSM modules are used to transmit location details to registered contacts through SMS and call alerts. The Blynk mobile application enables real-time monitoring and manual SOS activation, improving user interaction and accessibility. However, the system relies heavily on mobile app connectivity and focuses mainly on collision detection, with limited support for additional safety features such as fire detection, obstacle prevention, or autonomous control, motivating the need for a more comprehensive safety solution [1].

Harish Kumar *et al.* proposed an IoT-based accident detection and intelligent navigation system aimed at reducing emergency response time in urban environments. The system detects accidents using gyroscope and GPS data and transmits the location to a centralized server, which assists ambulances by providing the shortest route and controlling traffic signals using RF communication. While the approach effectively addresses traffic congestion and emergency vehicle navigation, it relies on infrastructure-level support such as traffic signal integration and centralized servers. Additionally, the system primarily focuses on post-accident navigation rather than incorporating in-vehicle multi-sensor safety features such as obstacle detection, fire hazard monitoring, or direct user-controlled emergency alerts, highlighting the need for a more self-contained and comprehensive accident detection solution [2].

Harish Kumar *et al.* proposed an IoT-based obstacle detection and alerting system using ultrasonic sensors mounted on a servo motor to monitor obstacles around a vehicle in real time. The system measures obstacle distance over a 0° to 180° range and alerts the driver through a visual interface, enabling collision avoidance in dynamic traffic conditions. While the approach is effective for short-range obstacle detection and cost-efficient implementation, it primarily focuses on collision prevention and does not address post-accident emergency handling, location-based alerting, or communication with emergency services, indicating the need for integrating obstacle detection with accident detection and emergency notification mechanisms [3].

Saminathan *et al.* proposed an IoT-based early fire detection system for electric vehicles that employs a **smoke sensor** to identify the presence of smoke at an early stage and generate real-time alerts. The system continuously monitors smoke levels using embedded sensors and triggers warnings when abnormal conditions are detected, thereby enhancing vehicle fire safety. Although the approach effectively detects fire-related hazards, it primarily focuses on smoke detection and does not incorporate vehicle collision detection, obstacle monitoring, or integrated emergency alert mechanisms, highlighting the need for a unified multi-sensor vehicle safety framework [4].

Sharma and Sebastian proposed an IoT-based car accident detection and notification system using smart sensors integrated with a microcontroller, along with GPS and GSM modules for location tracking and emergency alerts. The system detects accidents based on sensor inputs and immediately notifies registered contacts and nearby emergency services to reduce response time. Although the approach effectively addresses accident detection and notification, it primarily focuses on collision events and does not integrate additional safety features such as obstacle detection, fire or smoke monitoring, or remote control capabilities, indicating scope for a more comprehensive multi-sensor safety system [5].

Miclea *et al.* presented a comprehensive review of visibility enhancement and fog detection techniques for mobile and vehicular systems, covering image processing, sensor-based methods, and optical measurement approaches. The study highlights the importance of environmental awareness, particularly fog detection, in improving road safety and reducing accident risks under poor visibility conditions. However, the work is primarily focused on visibility estimation and does not address direct vehicle accident detection, collision alerting, or emergency communication mechanisms, indicating scope for integrating environmental sensing with real-time accident detection and safety alert systems [6].

Gomathy *et al.* developed an accident detection and alert system that utilizes accelerometer and vibration sensors to identify vehicle crashes and automatically notify emergency services using GPS and GSM modules. The system also incorporates an Android application to transmit accident location details to nearby hospitals and registered contacts, thereby reducing emergency response time. Although the approach effectively enables automatic accident reporting, it relies heavily on smartphone-based sensing and focuses mainly on collision detection, without integrating additional safety features such as obstacle detection, smoke-based fire detection, or autonomous control capabilities [7].

Kalyani *et al.* presented an accident detection and alert system using an Arduino-based architecture with vibration sensors to identify collision events and GPS–GSM modules to transmit accident location details to registered mobile numbers. The system focuses on rapid accident notification and basic location tracking to reduce emergency response time. However, the approach mainly relies on vibration-based detection and does not integrate advanced safety features such as obstacle detection, smoke-based fire detection, or multi-sensor decision-making, indicating the need for a more comprehensive IoT-based safety framework [8].

Alshamsi *et al.* proposed a real-time vehicle tracking system using an Arduino Mega integrated with GPS and GSM modules to continuously monitor vehicle location and transmit coordinates to authorized users via SMS and Google Maps. The system is mainly designed for vehicle security, fleet monitoring, and theft prevention, with features such as SOS alerts and engine control. However, the work primarily focuses on tracking and monitoring functions and does not address automatic accident detection, collision sensing, or integrated emergency alert mechanisms, highlighting the need to combine vehicle tracking with intelligent accident detection and safety alert systems [9].

Kanmani *et al.* proposed a vehicle tracking and accident detection system using an Arduino-based platform integrated with GPS and GSM modules to identify accident events and transmit location information to predefined contacts. A vibration sensor is used to detect collisions, while the system also supports vehicle tracking through SMS and Google Maps. Although the approach effectively combines tracking and accident alerting, it mainly relies on vibration-based detection and does not incorporate advanced safety mechanisms such as obstacle detection, smoke-based fire monitoring, or multi-sensor decision fusion, leaving scope for a more comprehensive IoT-based safety solution [10].

A. *Research Gap*

The Blynk- and Arduino-based collision alert system relies heavily on smartphone applications and stable internet connectivity, which may limit reliability in low-network or remote areas. Moreover, the system focuses mainly on collision detection and lacks integrated safety features such as obstacle detection, smoke monitoring, and multi-sensor emergency handling [1].

The intelligent navigation system relies on centralized servers, traffic signal infrastructure, and continuous network connectivity, which limits its reliability in remote or low-signal environments. Additionally, the system focuses on post-accident ambulance navigation and lacks in-vehicle multi-sensor safety features such as obstacle detection, fire or smoke monitoring, and autonomous emergency alerting [2].

The ultrasonic sensor–based obstacle detection system effectively helps in collision avoidance by alerting drivers about nearby obstacles. However, it focuses only on preventive obstacle detection and does not integrate accident detection, location tracking, or emergency alert mechanisms required for post-accident response [3].

The early fire detection system for electric vehicle batteries effectively identifies fire risks using IoT and machine learning techniques; however, it is limited to battery safety monitoring only. The system does not address vehicle collision detection, obstacle monitoring, or integrated emergency alerting, highlighting the need for a unified multi-sensor vehicle safety framework [4].

The IoT-based car accident detection system effectively identifies accidents and sends location-based alerts using GPS and GSM modules. However, it mainly relies on sensor-triggered collision detection and does not integrate preventive mechanisms such as obstacle avoidance or fire/smoke detection. This highlights the need for a unified multi-sensor safety system that combines accident detection with preventive and emergency response features [5].

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The fog detection and visibility enhancement methods mainly focus on improving driver awareness under poor weather conditions.They do not support accident detection, emergency alerting, or real-time location tracking. This highlights the need for an integrated IoT-based vehicle safety system with multi-sensor support [6].

The accident detection system relies mainly on smartphone sensors and vibration-based detection, which may fail if the mobile device is damaged or network connectivity is unavailable. It lacks integrated multi-sensor safety features such as obstacle detection, smoke or fire monitoring, and autonomous emergency handling [7].

The accident alert system primarily relies on vibration-based detection using Arduino, which may lead to false alerts and limited accuracy under real driving conditions. It does not integrate advanced safety features such as obstacle detection, smoke or fire sensing, or multi-sensor decision-making, indicating the need for a more comprehensive IoT-based vehicle safety solution [8].

The real-time vehicle tracking system effectively provides continuous location monitoring using GPS and GSM technology, mainly for security and theft prevention. However, it does not incorporate automatic accident detection, collision sensing, or integrated emergency response mechanisms, indicating the need for combining tracking with intelligent safety alert systems [9].

The vehicle tracking and accident detection system relies mainly on vibration-based sensing for identifying accidents and GPS–GSM modules for alerting. However, it does not integrate preventive safety features such as obstacle detection, smoke or fire monitoring, or multi-sensor fusion, indicating the need for a more comprehensive IoT-based vehicle safety framework [10].

B. Objectives

To design and implement an IoT-based accident collision detection system using an ESP32 microcontroller that can automatically identify vehicle collisions and initiate emergency response without human intervention.

To integrate real-time location tracking and communication by combining GPS and GSM modules to transmit accurate accident coordinates as Google Maps links to predefined emergency contacts.

To enhance vehicle safety through multi-sensor monitoring, including obstacle detection and smoke/fire detection, enabling automatic vehicle stoppage and hazard-specific alert generation.

To develop a low-cost, scalable, and reliable safety framework with manual SOS functionality and a Wi-Fi-based web interface, making the system suitable for smart vehicles and intelligent transportation applications.

III. PROPOSED METHODOLOGY

The proposed system is an IoT-based accident collision detection and safety alert framework centered on the ESP32 microcontroller, which functions as the main processing and control unit. The ESP32 continuously monitors sensor data and executes safety actions in real time.

Collision detection is achieved using a limit switch mounted on the vehicle, which is triggered during impact events. When activated, the ESP32 immediately recognizes the collision and initiates emergency handling procedures.

Obstacle detection is performed using an ultrasonic sensor that continuously measures the distance between the vehicle and nearby objects. If an obstacle is detected within a critical range, the system stops the vehicle to prevent secondary collisions.

A smoke sensor is used to detect fire-related hazards by monitoring abnormal smoke levels around the vehicle. Upon detection, the ESP32 halts vehicle motion and triggers emergency alerts.

A manual SOS button allows the user to request emergency assistance during non-collision situations such as medical emergencies or breakdowns. The system prioritizes SOS events and processes them with immediate response.

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Real-time location tracking is provided by the GPS module, enabling the transmission of accurate coordinates during emergency events. Vehicle control is managed through a motor driver, while a Wi-Fi-based web server allows remote operation under normal conditions. Audio-visual alerts using a buzzer and LED provide clear indication of emergency states.

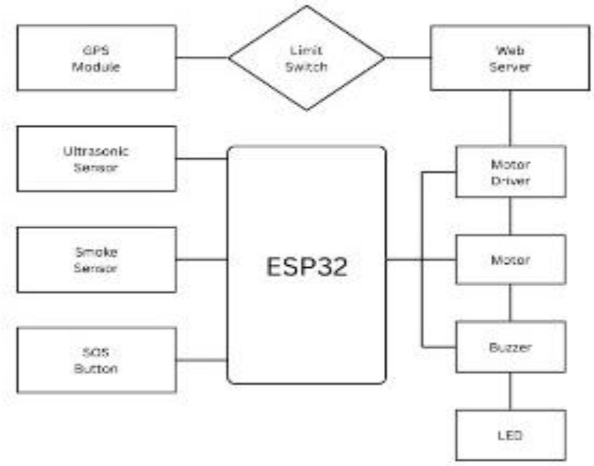

Fig 2: Block diagram of collision detection system

IV. RESULTS AND DISCUSSION

A. Implementation Method

The proposed system was implemented on a four-wheel robotic vehicle using an ESP32 microcontroller as the central control unit. All hardware modules were mounted on an acrylic chassis and interfaced to the ESP32 for real-time sensing and control. Collision detection was implemented using a front-mounted limit switch. When triggered, the ESP32 immediately stopped the motors and generated emergency alerts with real-time GPS location through the GSM module. An ultrasonic sensor was used to detect obstacles during vehicle movement. When an object was detected within a predefined safety distance, the system automatically halted the vehicle to prevent secondary collisions. Smoke detection was achieved using an MQ-2 sensor. Upon detecting abnormal smoke levels, the vehicle was stopped and alert notifications were generated, ensuring early fire hazard detection. A manual SOS button enabled user-initiated emergency alerts during non-collision situations. The experimental results confirmed reliable operation, accurate detection, and effective emergency response of the implemented system.

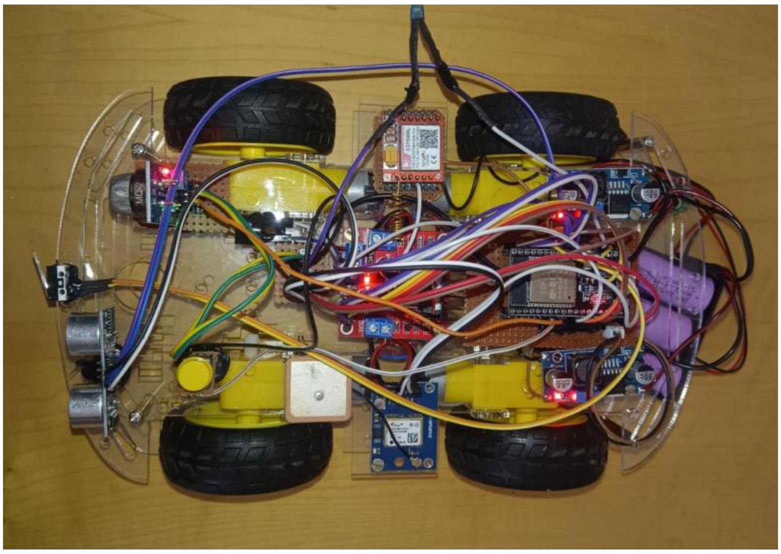

Fig 3: Interconnected hardware device.

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The ESP32 hosts a lightweight web server that enables real-time motor control through HTTP requests. Speed and directional commands are transmitted via a browser-based interface and processed by the ESP32 to control the motor driver, with safety logic overriding commands during emergency.

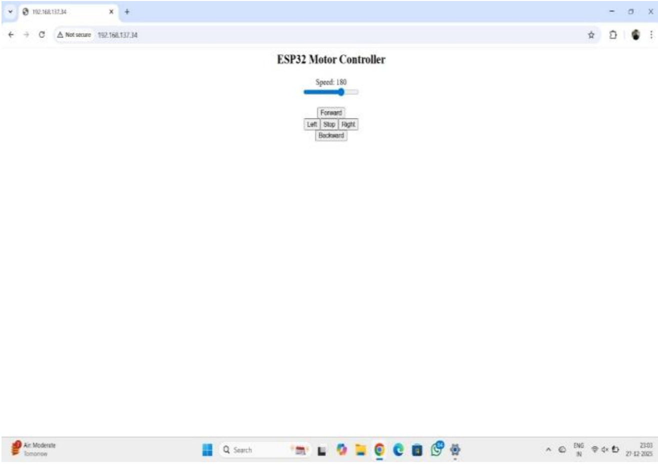

Fig 4: Web interface for remote motor control using ESP32

B. Result Outcome

The implemented IoT-based accident collision detection and safety alert system demonstrated reliable performance across all tested emergency scenarios. The system continuously monitored sensor inputs and responded immediately upon detecting abnormal conditions, ensuring timely alerts and improved emergency communication. All alert mechanisms were validated through real-time testing using GSM and GPS modules.

When a collision was detected using the limit switch, the ESP32 successfully triggered an emergency response by stopping the vehicle and initiating alert transmission. An SMS notification indicating "Accident Detected" was sent to the registered contact along with accurate GPS coordinates embedded as a Google Maps link. This enabled precise identification of the accident location and confirmed the effectiveness of real-time location tracking.

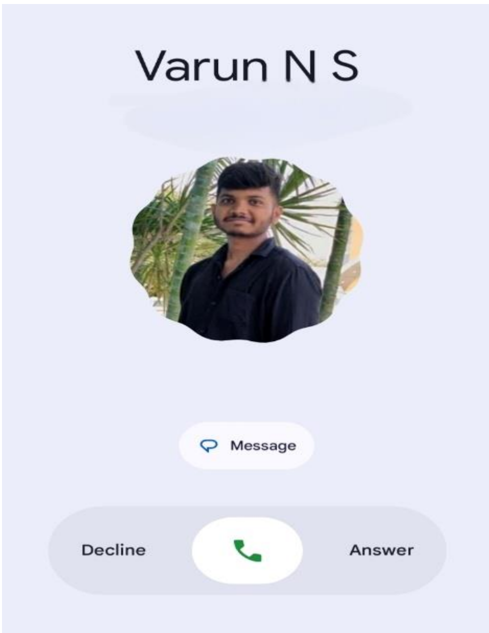

Fig 5: Incoming call alert

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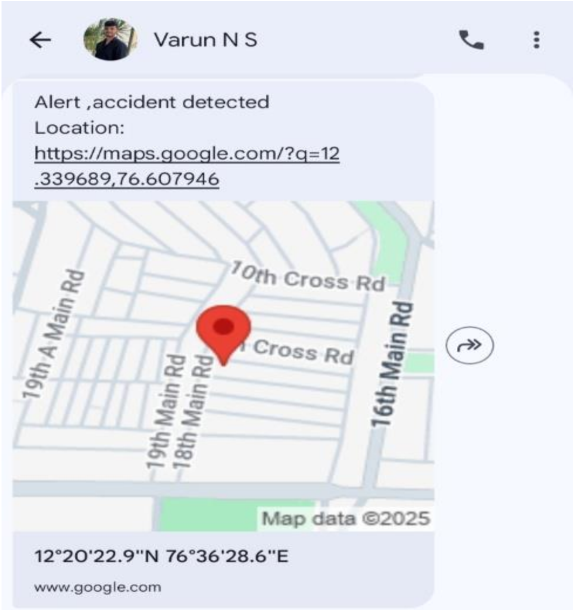

Fig 6: Location via SMS

The manual SOS functionality was also successfully tested. When the SOS button was pressed, the system immediately overrode normal operation and transmitted an emergency SOS alert with live GPS location details. This feature proved useful for non-collision emergencies such as medical conditions or breakdowns, ensuring user-initiated emergency communication.

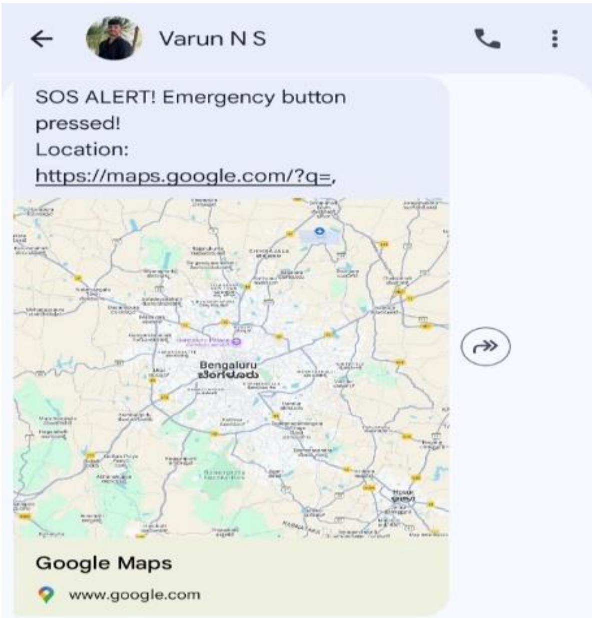

Fig 7: SOS alert with location information

Smoke detection tests showed consistent performance of the MQ-2 sensor. Upon detecting abnormal smoke levels, the system generated a "Smoke Detected" warning message and transmitted the location details instantly. This validated the system's ability to identify fire-related hazards early and provide timely alerts to prevent further damage.

In addition to SMS-based alerts, the GSM module initiated call alerts and generated missed-call notifications, as observed in the output screenshots. This dual-alert mechanism enhanced communication reliability by ensuring that emergency contacts received notifications even if SMS delivery was delayed or overlooked.

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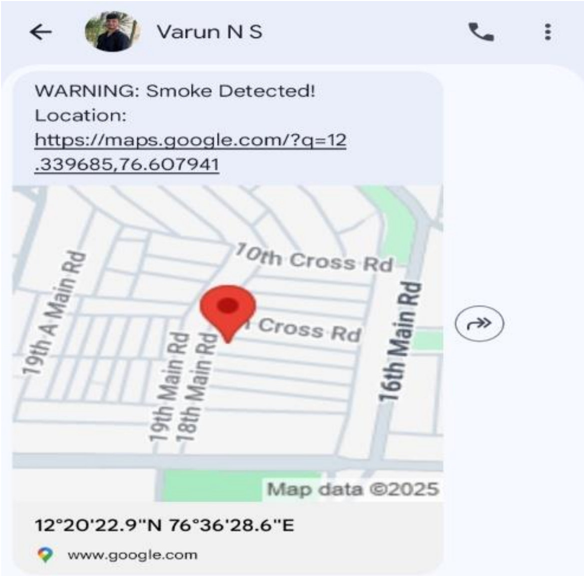

Fig 8: Smoke detected notification with location tracking

Overall, the experimental results confirm that the proposed system provides accurate detection, reliable location tracking, and effective emergency communication. The combination of multi-sensor detection, GSM-based alerts, and Google Maps integration demonstrates the system's suitability for real-time accident detection and safety applications in smart vehicles and intelligent transportation systems.

V. CONCLUSION

An IoT-based accident collision detection and safety alert system was successfully designed and implemented to enhance vehicle safety and reduce emergency response time. The system integrates multiple sensors with an ESP32 microcontroller to detect collisions, obstacles, smoke hazards, and user-initiated emergencies in real time. Automatic vehicle stoppage and immediate alert generation ensure prompt response during critical situations. Experimental evaluation confirmed accurate accident detection, reliable GPS-based location tracking, and effective emergency communication through GSM-based SMS and call alerts with Google Maps integration. The developed Wi-Fi-based web interface further improved operational flexibility by enabling remote vehicle control while maintaining sensor-driven safety priority. The proposed system provides a low-cost, scalable, and dependable solution suitable for smart vehicles and intelligent transportation systems. By minimizing reliance on manual intervention and ensuring timely emergency notifications, the system contributes to improved road safety and efficient emergency management.

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