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In-Vehicle Traffic Accident Detection and Alerting System Using Distance- Time Based Parameters and Radar Range Algorithm

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ABSTRACT

Road traffic accidents are a major cause of fatalities and injuries worldwide, often due to delayed detection and emergency response. To address this issue, this project proposes an intelligent in-vehicle accident detection and alerting system based on distance–time parameters and radar range algorithms. The system is developed using the ESP32 microcontroller, which provides high processing capability along with wireless communication. Ultrasonic and radar sensors are used to continuously monitor the distance between the vehicle and surrounding objects. Accelerometer and gyroscope sensors detect sudden impacts, abnormal acceleration, and vehicle orientation changes during collisions or rollovers. A GPS module provides real-time vehicle location and speed data. By combining distance–time calculations with radar-based range detection, the system

accurately identifies potential and actual accident scenarios. Once an accident is detected, emergency alerts containing location details are transmitted automatically. The proposed system enhances road safety by ensuring rapid accident detection and timely emergency notification. It is cost-effective, reliable, and suitable for real-time vehicular safety applications.

INTRODUCTION

Traffic accidents pose a serious threat to public safety and cause significant loss of life and property each year. Many accident-related fatalities occur due to delayed medical assistance after the incident. Traditional accident detection systems rely heavily on human intervention or manual reporting. With the advancement of embedded systems and IoT technologies, automated accident detection has become feasible. In-vehicle monitoring systems can

continuously analyze driving conditions and vehicle behavior. Distance–time based parameters help assess collision risks in real time. Radar range algorithms provide accurate object detection and speed measurement even in adverse weather conditions. Sensors such as accelerometers and gyroscopes help detect sudden impacts and vehicle instability. GPS modules enable precise location tracking for emergency alerts. ESP32 offers efficient data processing and wireless communication. This project aims to develop a smart accident detection and alerting system that minimizes response time and enhances road safety.

LITERATURE SURVEY

Several studies have focused on automated accident detection using sensor-based systems. Kumar et al. (2019) developed an accident detection system using accelerometers to identify sudden impacts. Sharma and Gupta (2020) proposed a GPS-based alerting system for emergency response. Verma et al. (2021) integrated gyroscope sensors to detect vehicle rollovers. Some researchers employed ultrasonic sensors for obstacle detection and collision avoidance. Radar-based vehicle detection systems have been widely studied for adaptive cruise control and

collision warning. Rao et al. (2020) used distance–time calculations to predict collision probability. IoT-based systems utilizing GSM and Wi-Fi modules have been proposed for alert transmission. However, GSM-based systems suffer from network delays. Camera-based approaches face issues in low visibility conditions. Many existing systems lack multi-sensor fusion for improved accuracy. Radar-only systems are costly for small vehicles. Sensor calibration and false detection remain challenges. Recent research highlights the importance of combining radar, inertial sensors, and GPS for robust accident detection. There is a need for an integrated, cost-effective solution using distance–time analysis and radar algorithms for real-time accident detection and alerting.

EXISTING SYSTEM

Existing accident detection systems mainly rely on manual reporting or emergency calls after an accident occurs. Some vehicles use airbag deployment signals to trigger alerts. Smartphone-based applications use accelerometer data to detect collisions but may generate false alarms. GSM-based alert systems have limited reliability due to network issues. Camera-based systems require high computational power and are

affected by lighting conditions. Many systems do not consider real-time distance measurement from nearby vehicles. Radar-based solutions are often expensive and complex. Existing systems may fail to detect minor collisions or rollover accidents accurately. Lack of sensor fusion reduces detection accuracy. Emergency response delays remain a major drawback. These limitations necessitate a smarter and more reliable in-vehicle accident detection system.

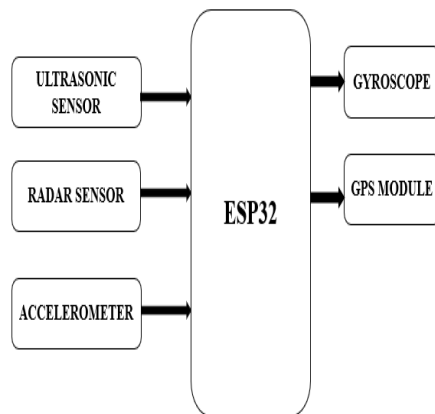
PROPOSED SYSTEM

The proposed system uses ESP32 as the central processing unit. Ultrasonic and radar sensors continuously measure the distance and relative speed of nearby objects. Distance-time parameters are calculated to assess collision risk. Radar range algorithms enhance object detection accuracy. Accelerometer and gyroscope sensors monitor sudden acceleration, impact forces, and vehicle orientation. GPS module provides real-time location and speed data. Sensor data is processed using predefined threshold and algorithmic conditions. When an accident is detected, the system confirms the event using multiple sensor inputs. Once validated, emergency alerts with GPS coordinates are transmitted wirelessly.

Radar Range Algorithm:

The algorithm begins by continuously acquiring distance measurements from ultrasonic and radar sensors to monitor nearby objects. Simultaneously, accelerometer and gyroscope sensors capture acceleration, tilt, and impact data of the vehicle. The system calculates the relative speed and distance between the vehicle and surrounding obstacles using distance-time parameters. Sensor data is processed in real-time by the ESP32 microcontroller to detect abnormal acceleration, sudden deceleration, or collision events. Radar range calculations help confirm potential accident scenarios by analyzing object proximity and velocity changes. GPS data is integrated to track the vehicle's exact location and speed at all times. When sensor readings indicate a probable accident, the algorithm verifies the event using combined motion and distance thresholds. Upon confirmation, an automatic alert containing the vehicle's GPS coordinates and accident details is generated. This alert is transmitted to predefined emergency contacts or control centers using ESP32's wireless communication. The algorithm ensures rapid detection, reducing response time and improving overall road safety.

BLOCK DIAGRAM



HARDWARE REQUIREMENT

ESP32



ESP32 is a low-cost, low-power microcontroller with integrated Wi-Fi and Bluetooth. It has dual-core processing capabilities, making it suitable for IoT applications. The board supports multiple GPIO pins for sensors and actuators. ESP32 can be programmed using Arduino IDE, MicroPython, or ESP-IDF. It features ADCs, DACs, and PWM for interfacing analog and digital devices. Its fast processing and wireless capabilities make it ideal for real-time monitoring systems.

ULTRASONIC SENSOR



An ultrasonic sensor is an electronic device used to measure distance by emitting high-frequency sound waves and receiving the reflected echoes from nearby objects. It works on the principle of time of flight, where the time taken for the sound wave to return is used to calculate distance. Ultrasonic sensors typically consist of a transmitter and a receiver. They are widely used for obstacle detection and distance measurement in robotics and automation systems. These sensors can accurately detect objects regardless of color, transparency, or lighting conditions. Ultrasonic sensors are commonly used in applications such as fire-fighting robots, parking assistance systems, and mobile robots.

GPS



GPS modules receive signals from satellites to determine geographic location. They provide latitude, longitude, altitude, and precise time information. Modules like Neo-6M are commonly used in navigation and tracking systems. GPS works outdoors and requires a clear line of sight to satellites. They are used in vehicles, smartphones, and IoT tracking devices. GPS enables real-time location tracking, route planning, and geofencing applications.

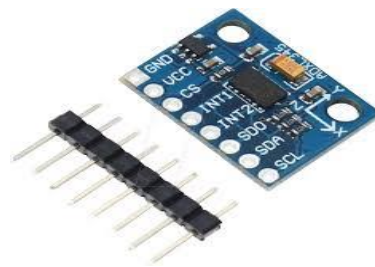
RADAR SENSORS



Radar sensors use radio waves to detect objects and their speed. They can operate in various weather conditions, unlike optical sensors. Doppler radar sensors measure velocity by detecting frequency shifts of reflected waves. They are widely used in automotive safety and traffic monitoring. Radar sensors provide long-range detection

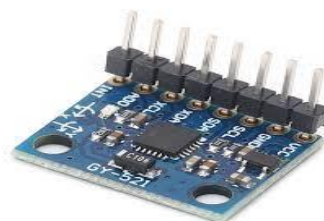
and high-speed object tracking. They are ideal for collision avoidance and real-time monitoring systems.

ACCELEROMETER



Accelerometers measure linear acceleration along one or more axes. They can detect motion, vibration, tilt, and orientation of a device. Commonly used in smartphones, wearables, and vehicle systems. MEMS accelerometers are compact, low-power, and highly sensitive. They output analog or digital signals proportional to acceleration. Accelerometers are crucial for detecting sudden movements or shocks.

GYROSCOPE



Gyroscopes measure angular velocity or rotational motion around axes. They help

determine orientation and stabilize moving platforms. MEMS gyroscopes are widely used in drones, robots, and mobile devices. They can work with accelerometers for accurate motion tracking. Gyroscopes are essential for navigation in GPS-denied environments. They provide real-time rotational data for control and monitoring systems.

SOFTWARE REQUIREMENT

Arduino Software (IDE)



The Arduino IDE (Integrated Development Environment) is a simple yet powerful platform used to program Arduino boards. It supports C and C++ programming languages with an easy-to-understand syntax tailored for microcontroller applications. The IDE provides a clean and intuitive interface where users can write, compile, and upload code directly to Arduino hardware. It includes a rich set of built-in libraries, making it easy to perform

common tasks such as reading sensors, controlling LEDs, or operating motors. The integrated Serial Monitor allows real-time communication and debugging between the Arduino and the computer. Compatible with Windows, macOS, and Linux, the IDE is accessible across multiple platforms. Users can extend its functionality using the built-in Library Manager, which offers access to numerous community-developed libraries. As an open-source tool, the Arduino IDE can be customized to fit specific development needs.

CONCLUSION

The proposed in-vehicle traffic accident detection and alerting system provides an effective solution for improving road safety. By combining distance-time based parameters with radar range algorithms and multiple sensors, the system ensures accurate accident detection. Automatic alert transmission reduces emergency response time and can save lives. The use of ESP32 makes the system cost-effective, efficient, and suitable for real-time applications. Future enhancements may include AI-based prediction and vehicle-to-vehicle communication.

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