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Accident Avoidance and Crash Detection Using GSM and GPS

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Abstract

The Accident Avoidance and Crash Detection system is designed to enhance vehicle safety by utilizing real-time accident detection, speed tracking, and automated crash prevention mechanisms integrated with GSM and GPS technologies. The system incorporates an accelerometer to identify abrupt changes in acceleration, indicating a potential collision. Upon detecting an accident, the system automatically transmits an alert message with the vehicle's GPS location to a designated mobile number using GSM technology, facilitating rapid assistance. Additionally, the system includes an over-speed monitoring feature where GPS data is used to continuously assess the vehicle's speed. If a predefined speed threshold is exceeded, the system issues a warning to the driver and can intervene to regulate the vehicle's speed, minimizing the risk of a crash. The ESP32 micro-controller acts as the central processing unit, managing sensor data, GPS integration, speed control mechanisms, and communication functionalities. This comprehensive system promotes road safety by ensuring prompt accident notifications, enforcing speed limits, and enabling crash detection, thus reducing road accidents and expediting emergency responses.

Keywords: GSM, avoidance, ESP32, ADXL345, GPS, crash detection, speed monitoring, real-time system

INTRODUCTION

Road accidents pose a significant global challenge, causing countless fatalities and injuries each year due to over-speeding, collisions, and delayed emergency responses. As a result, there is a pressing need for advanced safety systems to mitigate these risks and improve vehicular safety. The proposed project, Accident Avoidance and Crash Detection using GSM and GPS, addresses these issues by integrating sensors, communication technologies, and speed control mechanisms to identify accidents, monitor vehicle speed, and alert emergency services in real time.

The core component of the system is the ADXL345 accelerometer, which continuously tracks the vehicle's motion. Sudden deviations in acceleration patterns, indicative of an accident, trigger the system to send an alert. The GPS module pinpoints the vehicle’s location, while the GSM module communicates the incident details via SMS to pre-configured emergency contacts, including the accident's GPS coordinates for prompt action [1–7].

The system not only focuses on crash detection but also highlights the importance of speed monitoring. GPS data or an internal speed sensor

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calculates the vehicle's velocity, and when the predefined speed limit is breached, the system issues a warning to the driver. It can also regulate the vehicle's speed to prevent over-speeding-related accidents. The ESP32 micro-controller manages all operations, including data processing, module communication, and ensuring seamless execution of safety features.

This integrated approach aims to create a comprehensive solution that combines proactive accident prevention through speed regulation with reactive crash detection and immediate notifications. The system has the potential to significantly reduce road accidents, save lives, and provide timely assistance in emergencies.

LITERATURE REVIEW

Baballe (2023) [8]

In their study on an accident detection system employing GPS, GSM, and a buzzer, the researchers highlight the growing prevalence of road accidents due to the rapid rise in vehicular numbers globally. While technological advancements have simplified modern life, they have simultaneously heightened the risk of traffic hazards and accidents, often resulting in significant loss of life and property due to inadequate emergency services. Their findings indicate that fatalities from accidents are frequently linked to the inability to promptly inform medical authorities, leading to delays in providing critical care. The system proposed incorporates an accelerometer as a crash or rollover detector and a vibration sensor to assess vehicular vibrations. By analyzing data from these sensors, the system can identify severe accidents and promptly send an alert via the GSM module, including location data from the GPS module, to emergency services or vehicle owners. This approach ensures swift response times, particularly in remote areas, potentially saving lives by enabling quicker medical interventions [8].

Kushwaha *et al.* (2023) [9]

This study focuses on an automated accident detection and messaging system that leverages GSM and GPS technologies. It emphasizes the increasing number of road collisions and the resulting loss of life and property due to the growing vehicular population. According to the World Health Organization (WHO), road accidents claim approximately 1.35 million lives annually, with inadequate medical assistance at accident scenes being a primary contributor to fatalities. Modern vehicles often feature pre-installed smart monitoring systems to ensure operational safety and provide critical information to drivers. By integrating these technologies, the proposed system improves passenger safety by detecting accidents through vibration sensors and determining precise accident locations using GPS data. Notifications are then sent to registered contacts, including family members, emergency services, and nearby police stations, via GSM. The primary objective of this system is to reduce emergency response time and provide timely medical care, thereby mitigating accident-related fatalities, especially in isolated regions [9].

Butkar *et al.* (2022) [10]

This research highlights the importance of transportation systems in modern society while acknowledging the potential risks they pose, including road accidents. The study underscores the role of speed as a major risk factor, influencing both crash severity and the likelihood of an accident. Despite global efforts to promote safe driving, accidents continue to occur, often resulting in significant fatalities due to delayed emergency responses.

The authors present an automated accident detection system that leverages GPS and GSM technologies. GPS, originally developed for military purposes, is now widely used for navigation, location tracking, and logistics, providing precise data on position, speed, and timing. GSM technology complements GPS by enabling real-time data transmission, including text and voice communications. The integration of these technologies allows the proposed system to detect accidents and notify emergency services with accurate location details, ensuring a rapid response to potentially life-threatening situations [10].

Manish and Collaborators (2022)

The primary aim of this research is to address the rising number of road accidents and reduce the associated loss of lives and property. The proposed system utilizes IoT-based GPS and GSM technologies to detect accidents and notify emergency services and the driver's primary contacts. By minimizing the time taken for emergency responders to reach accident sites, this system enhances user safety and provides reassurance to their families. GPS technology is employed to accurately determine the accident location, while GSM ensures reliable communication of alerts. The study emphasizes the significance of integrating these technologies to improve emergency response efficiency and save lives in critical situations [11].

CIRCUIT DIAGRAM

Figure 1 shows the circuit diagram of an IoT-based accident detection and alert system using NodeMCU with GPS, GSM, and accelerometer modules.

METHODOLOGY

System Design and Architecture

- *Requirements Identification:* Define the system's primary objectives, including accident detection, real-time location tracking, speed monitoring, speed regulation, and alert notifications.
- *Hardware Selection:* Select suitable components for achieving the system's functionality:
  - *ADXL345 (Accelerometer):* To monitor abrupt movements or impacts associated with accidents.
  - *GPS Module (NEO-6M):* For precise tracking of the vehicle's location in case of an accident or speeding.
  - *GSM Module (SIM900A):* To relay alerts to specified phone numbers via SMS in the event of accidents or speed limit violations.
  - *ESP32 Micro-controller:* The central processor that handles sensor data and coordinates communication between modules.
  - *Speed Control Mechanism (optional):* Incorporate a motor controller or electronic throttle to manage speed if necessary.

Sensor Integration and Calibration

- *Accelerometer Integration:* Connect the ADXL345 sensor to the ESP32 and configure it to detect rapid acceleration changes. Set appropriate thresholds for crash detection.
- *GPS Module Configuration:* Link the GPS module with the ESP32 to ensure accurate reception and processing of location data.
- *Speed Monitoring:* Use GPS-derived speed data or an additional sensor to monitor vehicle speed and define a threshold for over-speeding.

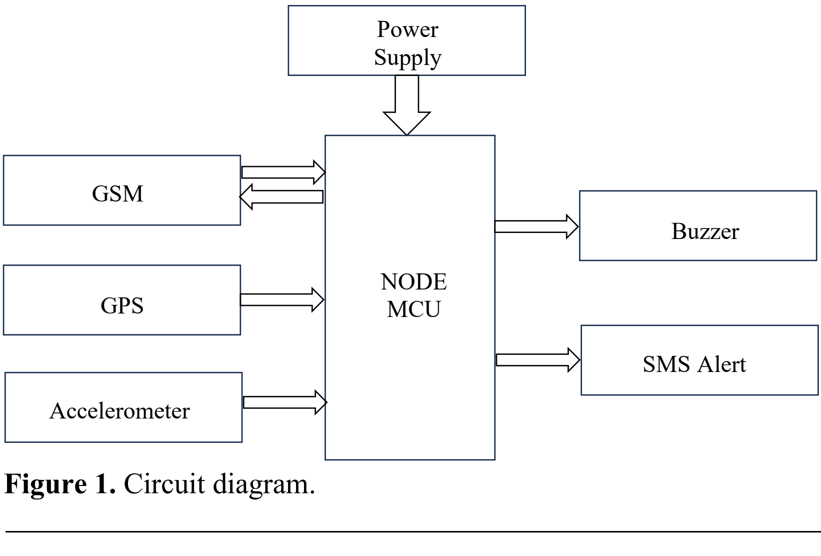

Figure 1. Circuit diagram.

Data Processing and Accident Detection Algorithm

- *Continuous Data Collection:* Monitor real-time data from the accelerometer and GPS modules during vehicle operation.
- *Accident Detection:*
  - o Develop an algorithm that identifies accidents by detecting sudden spikes in acceleration or deceleration beyond a preset threshold.
  - o Assess sensor data for abnormal movement patterns or impacts and flag significant deviations as potential accidents.
- *Over-speed Monitoring:* Establish a speed limit (e.g., 60 km/h) and use GPS data to monitor the vehicle's speed. Flag any violation of the threshold.

GSM-Based Notification System

- *Alert Notifications:* When an accident or over-speeding event is detected, the ESP32 will trigger the GSM module to send SMS alerts containing:
  - o An Accident Alert with precise GPS coordinates.
  - o An Over-Speed Alert indicating a breach of the speed limit.
- *Preloaded Contact List:* Maintain a set of emergency contacts, including family members and emergency services, in the ESP32's memory.

Speed Control and Mitigation

- *Speed Control Mechanism:* Implement measures for managing over-speeding scenarios:
  - o *Manual Warnings:* Alert the driver through an audible buzzer or visual indicator.
  - o *Automatic Speed Adjustment:* If feasible, integrate with the vehicle's throttle or electronic control unit (ECU) to reduce speed automatically.

Testing and Calibration

- *Accident Detection Validation:* Simulate various crash scenarios to fine-tune acceleration thresholds and test the system's sensitivity.
- *Speed Monitoring Validation:* Conduct controlled tests to verify the system's accuracy in detecting speed limit violations.
- *Communication Testing:* Confirm that GPS coordinates are accurately transmitted via SMS under diverse environmental conditions, such as open areas and urban zones.

Integration and Final Deployment

- *Component Assembly:* Consolidate all hardware into a compact and durable unit suitable for vehicle mounting. Include protective casings for resilience against environmental factors.
- *User Interface (Optional):* If applicable, integrate a display (e.g., an OLED screen) to provide real-time feedback on system status, such as speed or accident detection.
- *Field Testing and Deployment:* Deploy the system in real-world conditions to ensure its reliability and accuracy during actual accident scenarios.

Future Improvements and Enhancements

- *Cloud-Based Real-time Monitoring:* Enable remote access to vehicle data for fleet management or enhanced emergency response.
- *Driver Behaviour Analysis:* Use advanced algorithms or machine learning to evaluate and promote safer driving practices.
- *Integration with Vehicle Diagnostics:* Incorporate onboard diagnostic tools (e.g., OBD-II) for comprehensive insights into vehicle health and performance [12–17].

RESULTS

Over Speed Alert

This project includes an essential feature that ensures vehicle safety by notifying both the driver and emergency contacts when the vehicle exceeds a predefined speed limit (Figures 2 and 3). The system sends an SMS alert to a designated mobile number, enabling immediate action. Below is a detailed explanation of the feature's functionality, including speed monitoring, over-speed detection, and SMS notification using the GSM module (Figure 2).

Speed Monitoring Using GPS

- *GPS Integration:* The NEO-6M GPS module continuously tracks the vehicle's real-time speed, location, and trajectory. By triangulating signals from orbiting satellites, it accurately calculates the vehicle's velocity.
- *Speed Data Processing:* The GPS module relays speed data to the ESP32 microcontroller, which processes it in real time to monitor the vehicle's speed in kilometers per hour (km/h).

Defining the Speed Limit

- *Predefined Threshold:* A speed limit, such as 60 km/h, is set as the over-speed threshold.
- *Why Threshold Matters:* The limit is based on urban speed regulations and can be adjusted for specific use cases or road conditions.
- *Speed Comparison:* The ESP32 compares the vehicle's current speed with the set threshold. If the speed exceeds the limit, the system detects an over-speed condition.

Over-speed Detection Logic

- *Algorithm:* The ESP32 runs a simple detection logic:

```
if (currentSpeed > speedLimit) {
 sendOverSpeedAlert();
}
```

- *Triggering Alerts:* Once the vehicle's speed surpasses the threshold, the system calls a function (sendOverSpeedAlert) to notify the driver and emergency contacts.

Sending an SMS via GSM

Once the system detects over-speeding, the next task is to send an SMS alert to a predefined phone number using the GSM module (SIM900). The SMS will inform the recipient that the vehicle is over-speeding and provide relevant details like the vehicle's speed [18–25].

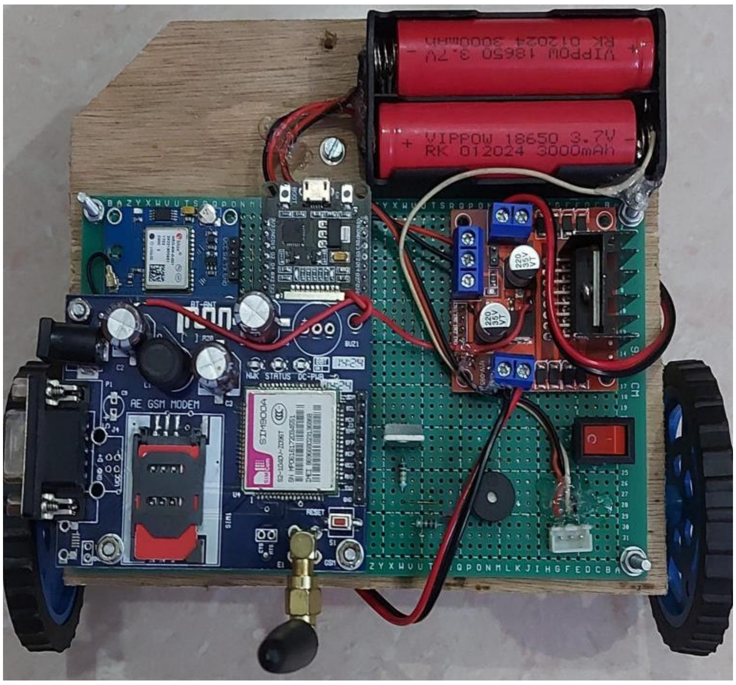

Figure 2. Over speed alert.

Steps for Sending the SMS

The process of sending an SMS using the GSM module involves several carefully structured steps to ensure reliable communication between the ESP32 and the GSM network. Below is a detailed breakdown of these steps, starting from establishing communication with the module to composing and transmitting the SMS.

Establish Communication with GSM

- The initial step is to establish a connection between the ESP32 micro-controller and the GSM module. This is achieved through serial communication, using the UART protocol. The GSM module's TX (transmit) pin is connected to the RX (receive) pin on the ESP32, while the RX pin of the GSM module is connected to the TX pin of the ESP32. Additionally, proper grounding is necessary, so the GND pins of both components should be linked.
- This configuration ensures that the ESP32 can send instructions to the GSM module and receive responses seamlessly. UART is particularly well-suited for this type of communication due to its simplicity and reliability in handling asynchronous data exchange.

Initialize the GSM Module

- Before the GSM module can perform its intended functions, it needs to be properly initialized. This involves sending specific AT commands, which are standard instructions used to configure and control GSM modules. These commands are transmitted via the serial interface, with the ESP32 serving as the host controller [26–31].
- A typical sequence for initialization:

Set Up Serial Communication

Begin by initializing serial communication between the ESP32 and the GSM module. This involves setting an appropriate baud rate (commonly 9600), which determines the speed of data transfer between the devices.

```
gsmSerial.begin(9600);
//Start serial communication
with GSM at 9600 baud rate
delay(2000);
//Wait for GSM module to
Stabilize
```

Check Module Connectivity

Send a basic "AT" command to verify that the GSM module is active and responsive. If the module is functioning correctly, it will return an "OK" response.

```
gsmSerial.println("AT");
// Check GSM connectivity
delay(1000);
// Allow time for a response
```

Set SMS Mode

Configure the GSM module to operate in text mode for sending SMS messages. This is achieved using the AT+CMGF command.

```
gsmSerial.println("AT+CMGF=
1"); // Enable SMS text mode
delay(1000);
```

Compose the SMS

- Once the GSM module is fully initialized, the next step is to prepare the content of the SMS message. This message serves as the notification that will be sent to the recipient. This step typically involves key details such as:
    - A notification about the event (e.g., over-speeding or an accident).
    - Additional details, such as the current speed or GPS location of the vehicle.

For example:

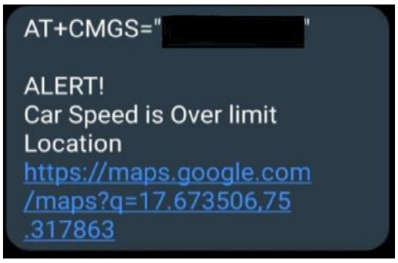

Figure 3. Over speed alert.

Send the SMS

- Sending the SMS involves a series of AT commands to specify the recipient's phone number, compose the message content, and transmit it via the GSM network. Here is how the process is executed:

Specify the Recipient:

Use the AT+CMGS command to enter the recipient's phone number. This command configures the GSM module to send a message to the designated phone number.

```
gsmSerial.print("AT+CMGS=\"+1234567890\"\r\n"); /replace with actual number
delay(100);
```

Send the Message Content:

Transmit the message content, followed by a special character (Ctrl+Z, represented as 26 in ASCII) to indicate the end of the message.

```
gsmSerial.print(message);
 //Send SMS content
delay(100);
gsmSerial.write(26);
//Send Ctrl+Z to finalize the
SMS delay(1000); // Allow
time for the message to be
sent
```

Handle Errors and Retries

To ensure reliability, the system monitors the GSM module's responses for confirmation that the SMS was successfully sent. If any errors occur, such as network unavailability or signal issues, the system can be programmed to retry the process after a short delay.

```
if (!messageSent) {
delay(5000); // Wait for 5 seconds before retrying sendOverSpeedAlert(); // Retry sending
the SMS }
```

Confirmation of SMS Delivery

Once the SMS has been sent, the GSM module may return a response indicating successful delivery. The ESP32 can read this response and log it, confirming that the notification has reached its intended recipient.

Accident Alert System

Accident Detection Using ADXL345 (Accelerometer)

The ADXL345 accelerometer plays a crucial role in identifying potential accidents by monitoring sudden movements or impacts. This sensor measures acceleration forces, allowing it to detect changes in the vehicle's motion and orientation.

Data Collection

The ESP32 micro-controller continuously gathers real-time data from the ADXL345 sensor, including linear acceleration and angular velocity. These parameters provide insights into both the vehicle's speed changes and rotational movements.

Setting Thresholds for Accident Detection

The system analyses the data for abrupt changes in acceleration or deceleration. Accidents are often characterized by sudden, high-intensity forces, which can be detected by setting threshold values. For instance:

- A sharp deceleration might indicate a collision or abrupt braking.
- A significant spike in acceleration could suggest an impact or crash. For example, if the sensor detects acceleration values exceeding a threshold (e.g., 35,000), the system flags it as a possible accident.

The system can be configured to detect such sudden changes by setting a threshold value for acceleration and deceleration. For example:

- If the acceleration value exceeds a certain threshold (e.g., more than 35000), it could be a sign of an accident.

Gyroscope Integration

To enhance accuracy, gyroscope data is used to monitor rotational motion. This helps identify events such as vehicle rollovers or flips. If large angular shifts are detected, the system considers this an abnormal motion indicative of a crash.

Accident Detection Mechanism

When the combined sensor readings exceed the configured thresholds, the ESP32 processes the information and classifies the event as an accident, triggering subsequent actions like sending alerts.

GPS for Location Tracking

In the event of an accident, sharing the precise location of the incident is critical for prompt assistance. The GPS module (NEO-6M) serves this purpose by providing accurate, real-time location data.

- *Real-Time Coordinates:* The GPS module continuously updates the latitude and longitude of the vehicle. This information is essential for determining the exact position of the accident.
- *Location Retrieval Upon Accident Detection:* Once an accident is identified, the ESP32 retrieves the current GPS coordinates. These details are included in the alert message sent to emergency contacts. By pinpointing the location, the system enables faster response times from rescue teams or family members.

Sending Accident Alert via SMS Using GSM module

Once the system detects an accident and retrieves the vehicle's location, it uses the GSM module (SIM900A) to send an SMS alert to a predefined list of emergency contacts (Figure 4). Below is the step-by-step process:

Step-by-Step Process of SMS Sending

GSM Initialization

- The ESP32 communicates with the GSM module using AT commands. This setup requires:
  - A notification that the vehicle has experienced an accident.

Message Composition

Once an accident is detected, the system prepares a predefined SMS message with the following information:

- A properly configured GSM module with an active SIM card capable of sending SMS.
- Establishing a stable UART-based communication between the ESP32 and GSM module.

Example message content:

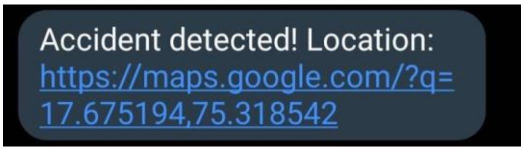

Figure 4. Accident alert.

Composing the Alert Message

- The system generates a predefined alert message containing:
    - Notification of the detected accident.
    - GPS coordinates, including latitude and longitude, are used for location tracking.

For instance, the following sequence of AT commands can be utilized:

```
AT+CMGF=1
// Configure the GSM module to
SMS text mode
AT+CMGS="recipient_number"
// specify the recipient's phone
Number
> "ALERT: An accident has
been detected with your vehicle!
Location: Latitude: 12.2839,
Longitude: 78.8968" // Press
Ctrl+Z or send ASCII code 26 to
transmit the message
```

Sending the SMS

- The ESP32 communicates with the GSM module by sending AT commands to enable SMS transmission.
- AT+CMGF=1: Sets the module to function in SMS text mode.
- AT+CMGS="phone_number": Specifies the recipient's phone number.
- The alert message is sent as text, followed by Ctrl+Z (ASCII 26) to indicate the end of the message and initiate transmission. For example:

```
gsmSerial.println("AT+CMG
F=1");
gsmSerial.println("AT+CMG
S=\"+1234567890\"");
gsmSerial.print("ALERT:
Accident detected!
Location: Lat: 12.3456,
Lon: 78.9012");
gsmSerial.write(26)
```

Error Handling and Retry Mechanism

- To ensure the message is delivered, the system monitors the GSM module's responses. If issues like poor signal strength or network errors occur, the system retries sending the SMS after a short delay. Multiple contact numbers can also be configured for redundancy [32–36].

Confirmation of Delivery

- The GSM module may return a status indicating successful delivery. The ESP32 can process this response to confirm that the alert has been sent successfully.

CONCLUSION

The Accident Avoidance and Crash Detection using GSM and GPS system is a significant leap forward in enhancing vehicle safety through the integration of modern technology. By combining real-time data processing, precise motion tracking, and seamless communication, this system offers a comprehensive solution to two critical aspects of road safety: accident detection and speed monitoring. Powered by the ESP32 micro-controller, the system effectively integrates the ADXL345 accelerometer for motion analysis, the NEO-6M GPS module for location tracking, and the SIM900A GSM module for reliable communication.

This project successfully addresses two primary objectives:

Accident Detection and Alerting

By leveraging the ADXL345 sensor, the system detects sudden impacts, abnormal motion patterns, or rollovers, indicating potential accidents. Upon identifying such an event, it promptly triggers an SMS alert to predefined emergency contacts. This alert includes critical information such as GPS coordinates, allowing for rapid response and timely intervention. This functionality is a crucial step in reducing response times during emergencies, potentially saving lives and minimizing the severity of injuries.

Over-speed Detection and Notification

Using real-time speed data from the GPS module, the system monitors the vehicle's velocity. If the speed exceeds a predefined safety threshold, the system sends an SMS alert to notify both the driver and emergency contacts. This proactive measure discourages reckless driving and helps foster safer road habits, potentially preventing accidents caused by excessive speeding.

In addition to these objectives, the system emphasizes reliability and efficiency by leveraging GSM technology for instant communication. Its modular design allows for scalability and customization, making it suitable for various vehicle types and applications. The integration of real-time monitoring and automated alerts ensures that critical information reaches the right people at the right time.

Moving forward, this system could be enhanced with additional features, such as cloud-based analytics for centralized monitoring, integration with vehicle control systems for automatic speed regulation, and advanced AI algorithms to analyze driver behavior. These improvements could extend its capabilities, making it not only a safety tool but also a cornerstone of intelligent transportation systems.

As road safety remains a critical global concern, this project demonstrates the immense potential of IoT-based solutions to address pressing challenges. By bridging the gap between technology and transportation safety, the Accident Avoidance and Crash Detection system represents a proactive and innovative approach to reducing accidents and improving response times, ultimately contributing to safer roads and saving countless lives.

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