Impact Based Crash Detection and Alert System using GSM, GPS & Accelerometer

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Abstract

Road accidents pose a significant threat to public safety, especially in areas with difficult topography or inadequate infrastructure, e.g., Nepal. This research paper presents an innovative Accident Alert System that integrates GSM, GPS, and an accelerometer sensor with Arduino microcontroller technology. The system is intended to deliver real-time accident detection and emergency response by notifying pre-selected emergency contacts with accurate accident location coordinates. The developed system is intended to overcome the shortcomings of remote areas delayed emergency response and increase survival rates. This paper describes the system design, how the system works, and performance assessment.

1. Introduction

Road crashes continue to be a problem worldwide resulting in serious injuries and death. The World Health Organization (WHO) estimates that more than 1.3 million people die every year from road crashes. The situation is made even worse in countries such as Nepal, where landslides, dilapidated roads, and delayed emergency services further deteriorate the situation.

Traditional accident detection systems, mainly used in developed countries such as the US and European countries, may require expensive instruments and sophisticated vehicle systems (e.g., the OnStar system in the US). However, such an approach is not economical or available in developing countries. This paper proposes a low-cost, efficient, and scalable Accident Alert System based on a combination of GSM, GPS, and accelerometer sensors. The objectives of this study are:

- To design a system capable of detecting vehicular crashes based on accelerometer data.
- To automatically alert emergency contacts with the vehicle's precise location using GSM and GPS modules.
- To evaluate the system's sensitivity, accuracy, and potential impact in regions with limited infrastructure.

2. Literature Review

Research has been conducted to develop accident detection and response systems. Key studies include:

- **WreckWatch System** : WreckWatch is a smartphone-based crash detection system that uses accelerometers and GPS sensors to monitor sudden impacts and send emergency alerts. Context-aware filtering, such as speed and motion thresholds, reduces false positives while maintaining accuracy (Chris Thompson et al.).

- **IoT-Based Accident Monitoring and Rescue System**: Studies conducted in developing regions emphasize the need for cost-effective, microcontroller-based solutions. These systems utilize accelerometers, GSM modules, and GPS receivers to automate crash detection and alert transmission.

These advancements demonstrate the potential of IoT-based systems to enhance road safety, particularly in underdeveloped regions like Nepal.

3. System Design and Components

The Accident Alert System is a high-performance, low-cost realization based on a hardware combination. Each component plays a distinct part in enabling the act of crash detection and emergency response:

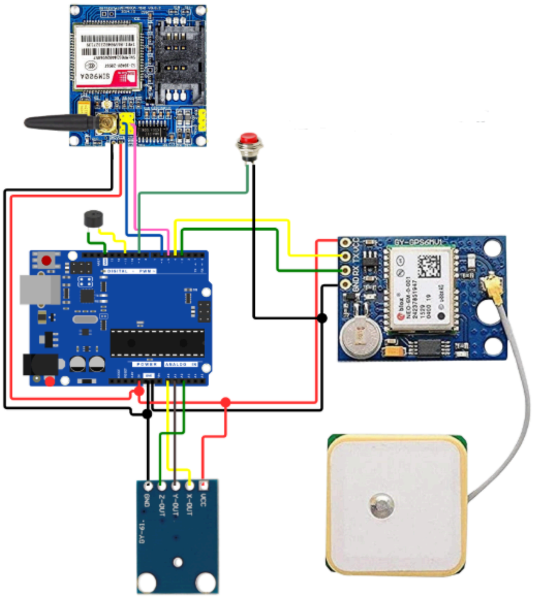

Fig 1.1 : Block Diagram of Components

1. Arduino Uno: The Arduino Uno microcontroller acts as the central processing unit of the system. It handles sensor data, crash condition understanding, and communication control between the accelerometer, GSM, and GPS modules. Arduino offers a powerful platform because of its ease of use, low power, and sensor application adaptability.

2. Accelerometer (GY-61): The accelerometer continuously tracks vehicle acceleration in three axes (x, y, and z). It detects any abrupt or unusual changes in motion patterns indicative of a crash. The accelerometer sends analog data to the Arduino, where the acceleration magnitude is computed.

3. GPS Module (NEO-6M): In this module, the coordinates of the vehicle (latitude and longitude) are obtained in real-time, by getting the latitude and longitude from GPS satellites. After a crash is identified, the GPS module transmits the exact geographic locations to the microcontroller and will continue transmission.

4. GSM Module (SIM900A): The GSM module is the communication core of the system. It automatically sends SMS alarms to predetermined emergency contacts (i.e., GPS coordinates). The

SIM900A module works properly when no internet connection is available providing confidence for remote applications.

5. Buzzer and Push Button: After detection, the buzzer generates a high-pitched sound during post-detection exhibiting a warning sound, and the push button allows users to stop false alarms within 10 seconds. If the alarm isn't stopped, the notification will be sent to the contacts.

4. Algorithm for Crash Detection

The algorithm of the Accident Alert System uses mathematical and logical logic to determine sensor data and activate emergency response. The following steps explain the system's operation:

1. Sensor Initialization and Calibration:
   At the system's initialization, baseline values for the accelerometer's x, y, and z axes are read and stored. These parameters define the vehicle's steady-state motion and are used as a baseline for later comparison.

2. Continuous Monitoring of Acceleration:
   The accelerometer measures acceleration using a high sampling rate. The unprocessed data is streamed to the microcontroller in real-time. The system tracks the rate of change (Δx, Δy, Δz) from baseline.

3. Magnitude Calculation:
   The rate of change of acceleration magnitude is computed according to the following:
   Here, changes in the acceleration values in the 3 directions are denoted by :

   X-axis (forward acceleration)
   Y-axis (side-to-side acceleration)
   Z-axis (vertical acceleration)

   The equation used to calculate the magnitude of the acceleration change is based on the Euclidean distance formula in three dimensions.

$$M = \sqrt{(x)^2 + (\Delta y)^2 + (\Delta z)^2}$$

$$Where:$$

$$\Delta x = x_{current} - x_{previous}$$
$$\Delta y = y_{current} - y_{previous}$$
$$\Delta z = z_{current} - z_{previous}$$

Normal Driving ng Conditions (Before the Crash):

When a car is driving normally, the accelerations in the x, y, and z directions would generally be small and relatively stable, as the car is moving on a flat surface at a constant speed. For simplicity, let's assume:

X-axis (forward acceleration): 0.2 m/s^2
Y-axis (side-to-side acceleration): 0.05 m/s^2
Z-axis (vertical acceleration): 0.1 m/s^2
These values represent small, constant accelerations that occur during normal driving.

Crash Scenario (During the Crash):

During a sudden crash, the accelerations would spike significantly due to the impact. The values could be much larger and will be felt instantaneously when the car hits an object. Let's assume:

X-axis (forward acceleration): 8 m/s^2 (a large spike forward due to the collision)
Y-axis (side-to-side acceleration): 1.5 m/s^2 (side forces during the crash)
Z-axis (vertical acceleration): 2.5 m/s^2 (vertical forces due to the sudden stop)

Using the formula above we can find that,
Magnitude ≈ 8.51

Example Data for Graph (Time vs Magnitude):

Time (s)	Magnitude
0	0.3
1	0.3
2	0.4
3	0.4
4	8.5
5	6.2
6	5.0
7	0.3

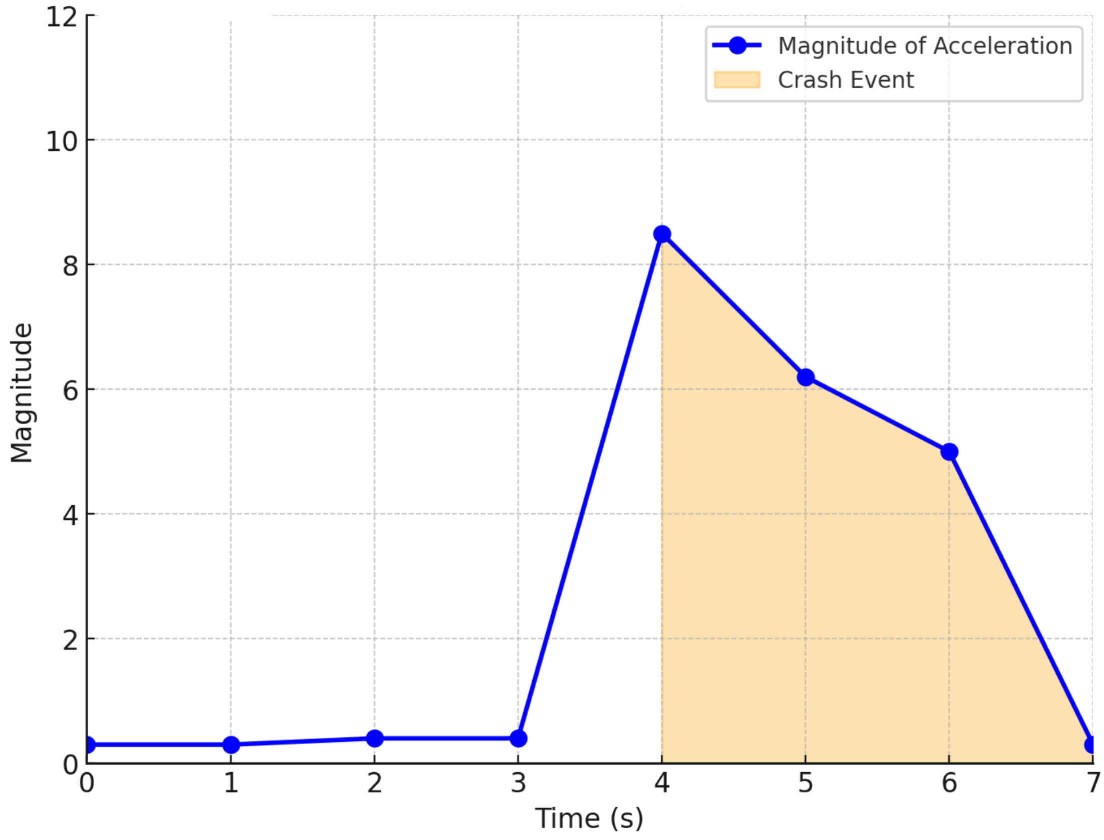

Fig 1.2 : Graph of Magnitude of Acceleration vs Time

4. Crash Detection Threshold:
   The system compares the computed magnitude against a predefined sensitivity threshold. If the system validates the occurrence of a crash, calibration of the gate is performed to the minimum false positive result due to sudden braking or small pacts.

5. False Alarm Handling:
   The push button serves as a manual override for false alarms. If triggered inside the buzzer's 10-s activate window, the system deactivates the alert and restarts.

6. Emergency Response Execution:
   Upon crash detection, the following actions are executed sequentially:

- The buzzer sounds for 10 seconds to draw the nearby attention and avoid the false alarm.
- The GPS module retrieves the vehicle's current coordinates.
- The GSM module sends an SMS to the preset emergency contacts. The message provides latitude and longitude coordinates along with a Google Maps link.

5. Results and Discussion

The system was tested in various simulated crash scenarios:

- **Sensitivity Testing**: Adjusted the sensitivity to detect crashes while avoiding false positives due to bumps.
- **Response Time**: The system successfully sent SMS alerts within 10-15 seconds of crash detection.
- **GPS Accuracy**: GPS coordinates were accurate within a 5-meter radius.

The proposed system utilizes a combination of Arduino, GSM, and GPS technologies to offer an efficient and low-cost solution. It operates without the need for an internet connection, ensuring accessibility in areas with limited or no connectivity. With a response time of 10-15 seconds, the system provides quick feedback and reliable performance. Given its affordability and minimal infrastructure requirements, the adoption feasibility in Nepal is considered high, especially in rural or remote areas where internet access may be inconsistent.

6. Conclusion

This paper presents an affordable and efficient Accident Alert System designed to detect vehicle crashes and provide real-time emergency alerts using GSM and GPS technologies. The lack of internet connection capability and low price of the system makes it very suitable for implementation in developing countries, such as Nepal. Next, work will be done to combine machine learning algorithms and thereby increase crash detection accuracy and expand the system with the ability to detect other parameters including vehicle rollover.

7. References

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