RESEARCH ARTICLE

Vehicle Accident Detection and Message Conveyor

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Abstract

Road accidents have become a critical concern in recent years, particularly due to unmanaged road conditions and challenging geographical terrains, leading to a significant rise in fatalities. Timely detection and rapid response to such incidents are crucial to reducing casualties. This paper presents the design and development of an electronic system, "Vehicle Accident Detection and SMS Conveyor," which automatically detects accident locations and communicates the incident to relevant authorities via SMS. The system integrates multiple sensors and modules, including an MPU-6050 (gyroscope and accelerometer), ESP32 microcontroller, GSM module, and GPS module. The MPU-6050 monitors vehicle tilt angles and sudden changes in speed, generating an interrupt signal to the ESP32 upon detecting abnormal conditions indicative of an accident. The ESP32 then retrieves the precise accident coordinates (latitude, longitude, and altitude), as well as the date and time, from the GPS module. Subsequently, the GSM module transmits an alert message to the nearest police station or rescue team. This system not only aids in real-time accident reporting but also facilitates efficient rescue operations and provides valuable data for post-incident investigations, contributing to improved transport management and road safety.

Keywords: vehicle information recorder, GPS locator, MPU 6050, ESP 32, GSM module.

1 Introduction

Road traffic accidents are one of the leading causes of fatalities worldwide, and the challenge is particularly. Severe in countries like Nepal, where road infrastructure is underdeveloped and geographical conditions are difficult. According to recent statistics, thousands of lives are lost annually due to delayed accident detection and the slow arrival of emergency services. For instance, in Kathmandu alone, the road death index has ranged between 0.4 and 0.9 per 1,000 population in recent years, with a total of 2,883 fatalities recorded nationwide as of October 31, 2022 [1]. This alarming statistic underscores the critical gap in timely emergency response, a challenge that persists despite various technological proposals [3, 6]. This underscores the urgent need for technological interventions to mitigate post-accident delays. The primary cause of these fatalities is not only the occurrence of accidents but also the delay in locating accident sites and initiating timely rescue operations.

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Existing accident reporting systems rely heavily on eyewitness accounts, manual communication, or post-incident analysis, making them slow and unreliable. In many scenarios-especially during nighttime or in remote regions-accidents remain undetected for hours, reducing the likelihood of survival for victims. Current state-of-the-art solutions include GPS tracking, MEMS accelerometers, and smartphone-based monitoring. While systems integrating GPS and MEMS sensors for accident monitoring have been explored [2], many remain reliant on manual triggering or lack integrated, real-time alerting mechanisms suitable for regions with poor connectivity, as noted in recent surveys [6]. As a result, there is a pressing need for an automated, standalone, and robust accident detection system that can detect accidents and immediately notify emergency services with precise location details. Existing systems often rely on internet connectivity or complex cloud infrastructure [4], making them unsuitable for regions with poor network coverage. While sensor fusion for detection is established [2], and system integration frameworks are discussed [5], a truly standalone solution combining reliable detection, precise GPS location, and direct GSM alerting for immediate use in diverse geographical terrains remains an unmet need. This study aims to address this gap.

This study introduces "Vehicle Accident Detection and Message Conveyor," an intelligent electronic system designed to automatically detect vehicle accidents and send real-time SMS notifications containing the accident's exact location (latitude, longitude, and altitude) to predefined authorities such as police stations or rescue teams. The system integrates MPU-6050 sensors (combining gyroscope and accelerometer functions) to monitor sudden changes in tilt angle or speed, which serve as indicators of a crash. An ESP32 microcontroller processes these signals, while a GPS module retrieves the vehicle's position, and a GSM module delivers the alert via SMS. This hardware-based, internet-independent system is designed to minimize reporting delays, especially in regions with poor connectivity, and has the potential to save lives by enabling faster emergency responses.

The methodology involves sensor fusion using the MPU-6050 for impact detection, GPS-based position tracking, and GSM communication for instant notifications. Unlike prior solutions, this design ensures real-time detection and direct communication without relying on cloud servers or mobile internet. Preliminary evaluations indicate that our prototype can reduce accident reporting time from several minutes (in conventional systems) to a few seconds. Moreover, the system logs data such as time, date, and location, which can later be used for post-incident investigation.

The main contributions of this paper are:

1. Development of a standalone accident detection system using low-cost, readily available components.
2. Real-time SMS alerting with accurate location data, improving emergency response efficiency.
3. A reproducible design that can be implemented in various transportation systems, especially in rural and hilly regions.

2 System Design and Implementation

An overview of the proposed vehicle accident detection and alerting system is illustrated in the block diagram of Figure 1.

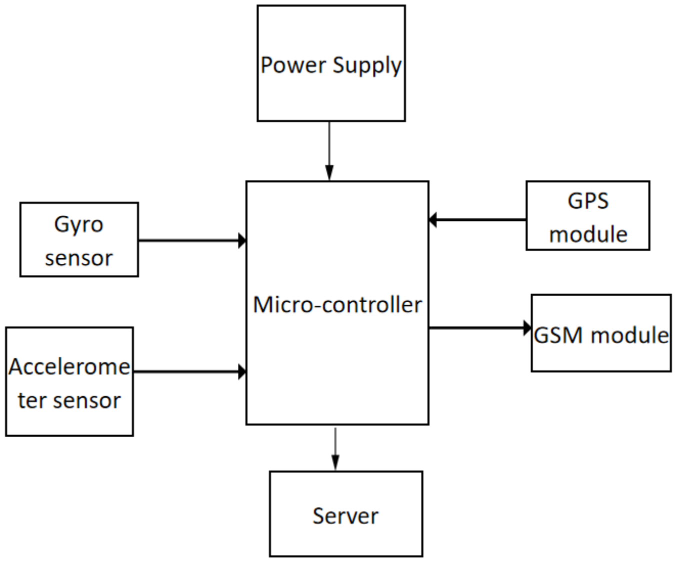

Figure 1. Block diagram.

Power supply is provided to all sensors respectively. The MPU 6050 is compact tool that is able to do work of gyro sensor and accelerometer. Accelerometer measures acceleration, which is the rate at which an object changes its velocity with respect to time. Gyro sensor measures the angular velocity, or the rate of rotation, of a vehicle around its three axes: roll, pitch, and yaw, commonly used in stability control systems and navigation systems. ESP32 includes up to 520 KB of SRAM, 4 MB of flash memory, and built-in Wi-Fi and Bluetooth connectivity. Finally, server is created using firebase locally. It takes information from ESP 32 microcontroller if accident occurs and sends SMS to police station. GSM allows a mobile device to communicate over a GSM network and essentially functions as a miniature mobile phone with a built-in SIM card slot and antenna, enabling to communicate with the internet or other devices via a cellular network. The logical workflow governing the interaction between these components, from accident detection to alert transmission, is depicted in the flowchart shown in Figure 2.

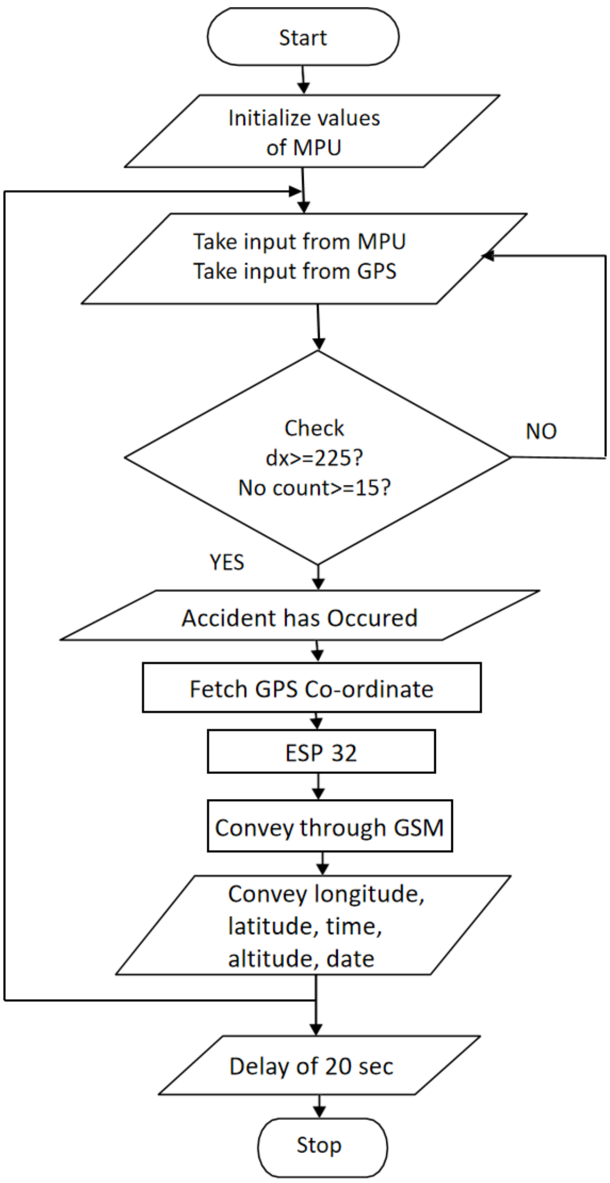

Figure 2. Flow chart.

a. Initially, rough idea and design is selected.

b. Estimation of equipment and sensors as MPU 6050, ESP 32, GPS module, GSM module, breadboard, connecting wires etc.

c. MPU 6050 works as accelerometer and gyro scope. A connection is made with MPU 6050, ESP 32 and GPS neo 7m module respectively with connecting wires.

d. Firebase and Arduino IDE is software platform used for web server and Arduino IDE for GPS module.

e. If either gyroscope sensor or accelerometer through MPU 6050, senses unusable data against normal condition then it triggers a signal to ESP 32.

f. ESP 32 is microcontroller that triggers GPS module. GPS module reads the current position of user and sends information to respective destination.

g. GSM module functions as a miniature mobile phone with a built-in SIM card slot and antenna, enabling devices such as GPS trackers, and other embedded devices to communicate with the internet or other devices via a cellular network.

2.1 Circuit Implementation and Interfacing

The interconnections between the ESP32 microcontroller, MPU-6050 sensor, and GPS module are detailed in the circuit diagram presented in Figure 3, with specific pin assignments described as follows. The ESP32 is interfaced with the MPU-6050 sensor and the NEO-7M GPS module. 3.3 V voltage is supplied to all modules and ground is connected to a common point. Pin 21 and 22 (data 0 and data 2) of ESP 32 is connected to SDA (Serial Data Pin) and SCL (pin no 24 and 23) (Serial clock pin) for i2c interface. Also UDRXD (pin 35) and UTXD (pin 34) of ESP 32 is connected to TX and RX respectively of GPS module. To transmit SMS, ESP 32 sends signal to GSM and GSM sends SMS message to defined number at police station.

2.2 Hardware

2.2.1 GPS Module

The system employs a u-blox NEO-7M GPS module (see Figure 4) for acquiring precise geolocation coordinates. Its key performance specifications are summarized in Table 1. GPS receivers are generally used in smart phones, fleet management system, military etc. for tracking or finding location. Global Positioning System (GPS) is a satellite-based system that uses satellites and ground stations to measure and compute its position on Earth. With real-time data and accurate location tracking, emergency services can

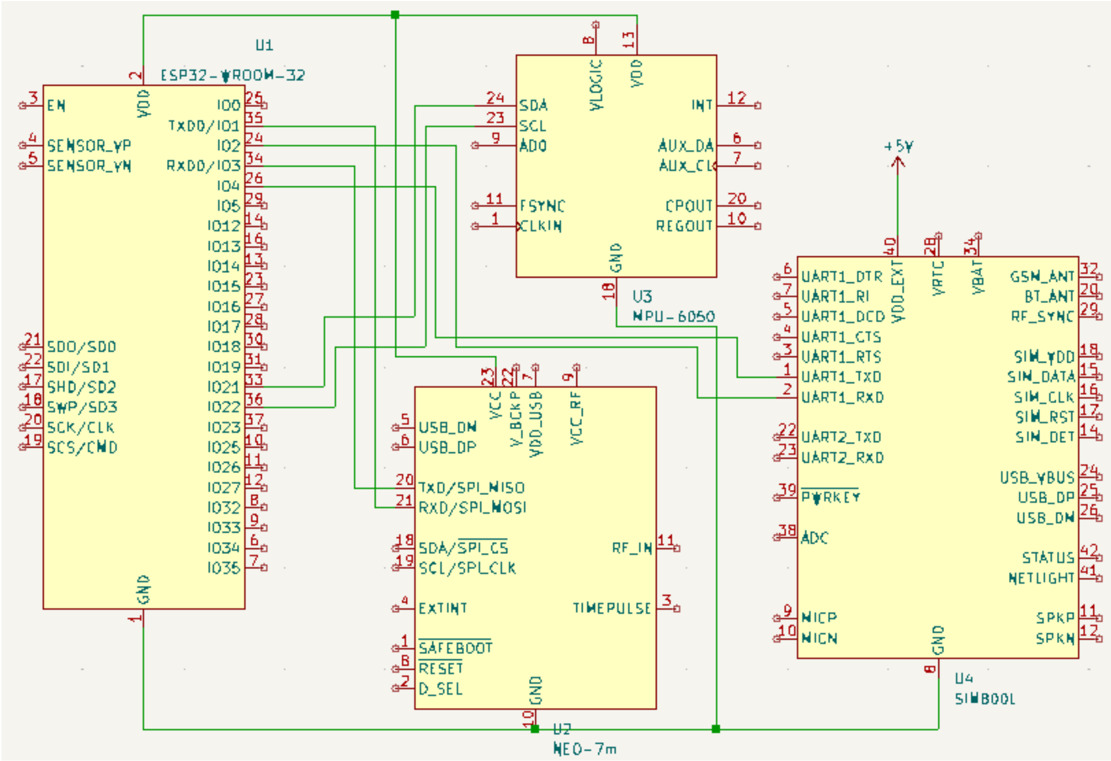

Figure 3. Circuit diagram.

respond more quickly to accidents. This can help to save lives and reduce the severity of injuries.

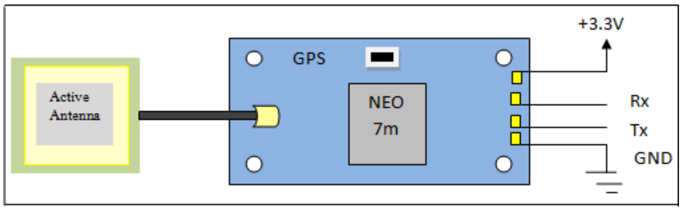

Figure 4. GPS module.

Table 1. Performance specification of GPS.

Parameter	Specification
Receiver Type	L1 frequency band, C/A code. 22 Tracking / 66 Acquisition-Channel.
Accuracy	Position: 3m 3D RMS without SA. Velocity: 0.1 m/s without SA. Timing (PPS): 60ns RMS.
Power Consumption	Tracking: < 30mA @ 3V Vcc. Acquisition: 40mA. Sleep/Standby: TBD.

2.2.2 *MPU-6050*

This sensor, shown in Figure 5, is configured to monitor real-time vehicle dynamics and generate an interrupt signal upon detecting patterns indicative of a collision or rollover. The MPU-6050 has a built-in 3-axis accelerometer which can measure acceleration in x, y, and z directions. The measured acceleration values can be read through the I2C interface. The MPU-6050 has a built-in motion detection function which can detect changes in motion and trigger an interrupt. It is connected with ESP 32 and GPS module for vehicle accident detection and transmits its position.

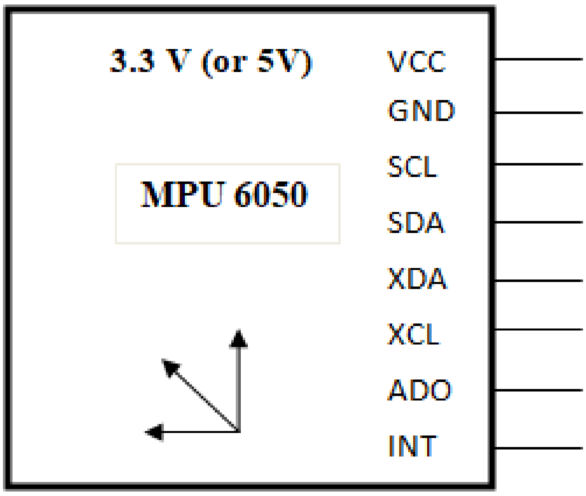

Figure 5. MPU 6050.

2.2.3 *ESP 32*

The specific development board used in this prototype, highlighting its accessible GPIO pins for sensor and module interfacing, is shown in Figure 6. ESP32 is a low-cost, low-power Microcontroller with an integrated Wi-Fi and Bluetooth. ESP32 can perform as a complete standalone system or as a slave device to a host MCU, reducing communication stack overhead on the main application processor. ESP32 can interface with other systems to provide Wi-Fi and Bluetooth functionality through its SPI / SDIO or I2C / UART interfaces.

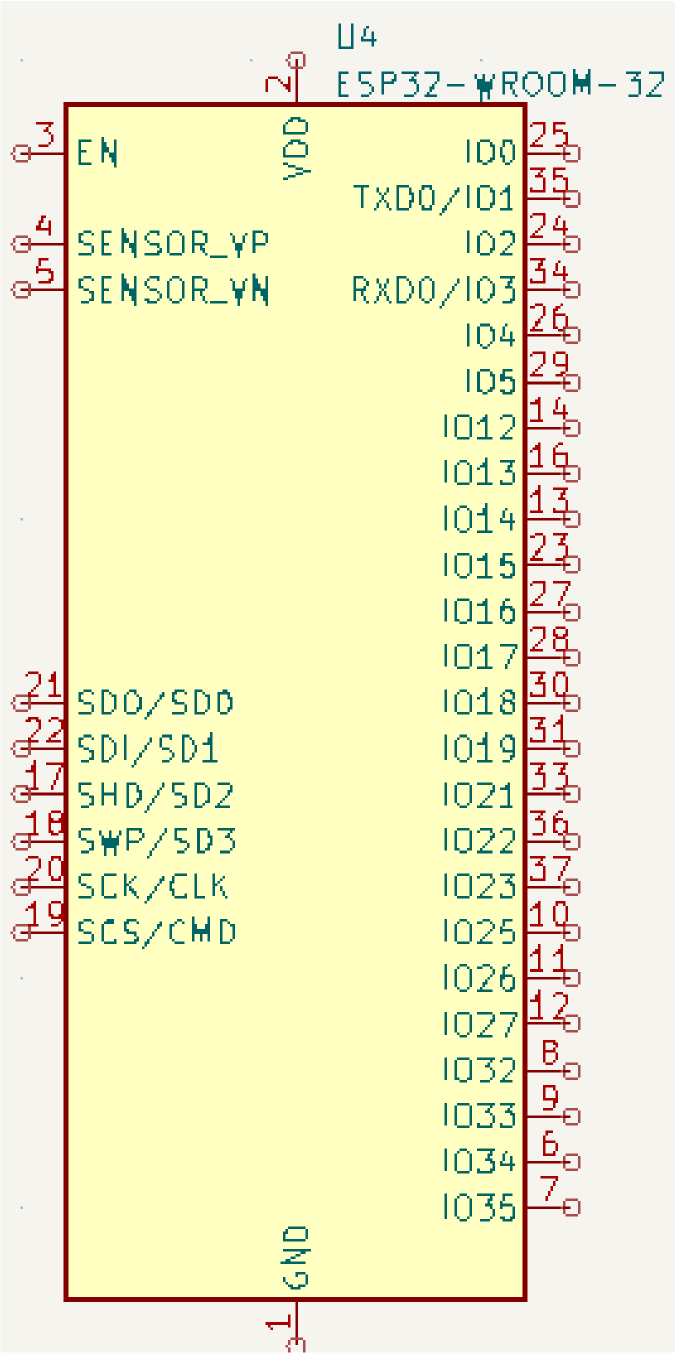

Figure 6. Circuit diagram of ESP 32.

2.2.4 *GSM Module*

Communication with emergency services is facilitated by a SIM800L GSM module. Figure 7 provides a pinout diagram of this module, which is essential for its proper integration with the ESP32's serial interface.

A GSM (Global System for Mobile Communications) module is a type of hardware device that allows a mobile device to communicate over a GSM network. It essentially functions as a miniature mobile phone with a built-in SIM card slot and antenna, enabling devices such as smart home systems, GPS trackers, and other embedded devices to communicate with the internet or other devices via a cellular network.

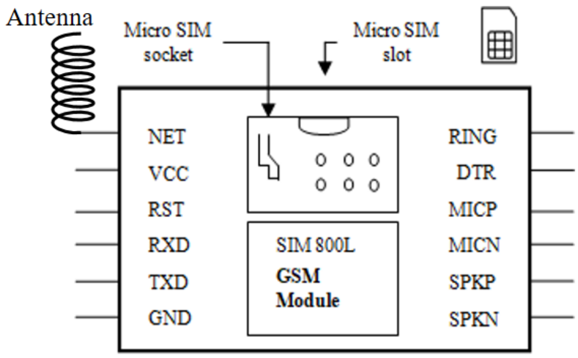

Figure 7. GSM pin diagram.

2.3 Software

2.3.1 *Arduino IDE*

Arduino Integrated Development Environment -or Arduino Software (IDE) -contains a text editor for writing code, a SMS area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. They make it easier to reuse code in other programs by making it more modular, and as a nice side effect, using functions also often makes the code more readable. There are two required functions in an Arduino sketch, setup () and loop (). Other functions must be created outside the brackets of those two functions. It is open-source software, which means that users can modify and redistribute it as they see fit. Some features are enlisted below:

- Easy to use
- Cross-platform
- Syntax highlighting
- Built-in serial monitor
- Library manager
- Open-source

2.3.2 *Firebase*

The Firebase Real-time Database helps to build rich, collaborative applications by allowing secure access

Table 2. Result from GPS.

Longitude	Latitude	Altitude	Date	Time	Driving Mode
27.65715350	85.31742950	1372.60m	2023-04-14	13:28:27	High disturb.
27.65715850	85.31742533	1375.10m	2023-03-14	13:28:29	High disturb.
27.65715467	85.31741133	1376.70m	2023-03-14	13:28:30	High disturb
27.65715667	85.31741667	1380.0m	2023-03-14	13:28:32	High disturb.

to the database directly from client-side code. Data is persisted locally, and even while offline, real-time events continue to fire, giving the end user a responsive experience. The Firebase Real-time Database is a cloud-hosted database. Data is stored as JSON and synchronized in real-time to every connected client. Some features are enlisted below:

- Incredibly Built-in Analytics
- Real Time Database
- App Development Mode Easy
- Growth and User Engagement

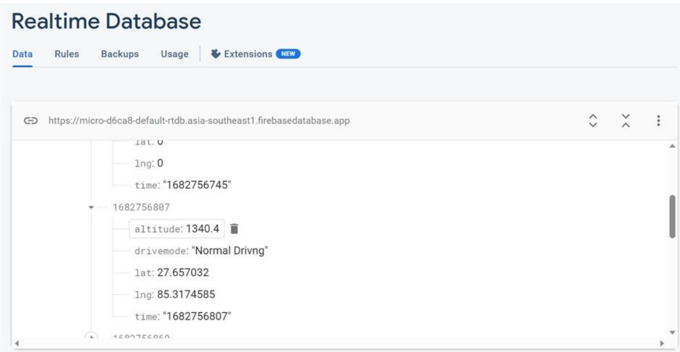

Figure 8. Normal driving mode.

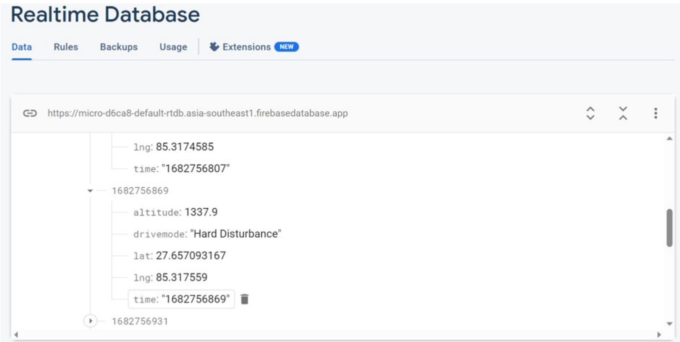

Figure 9. High disturbance mode.

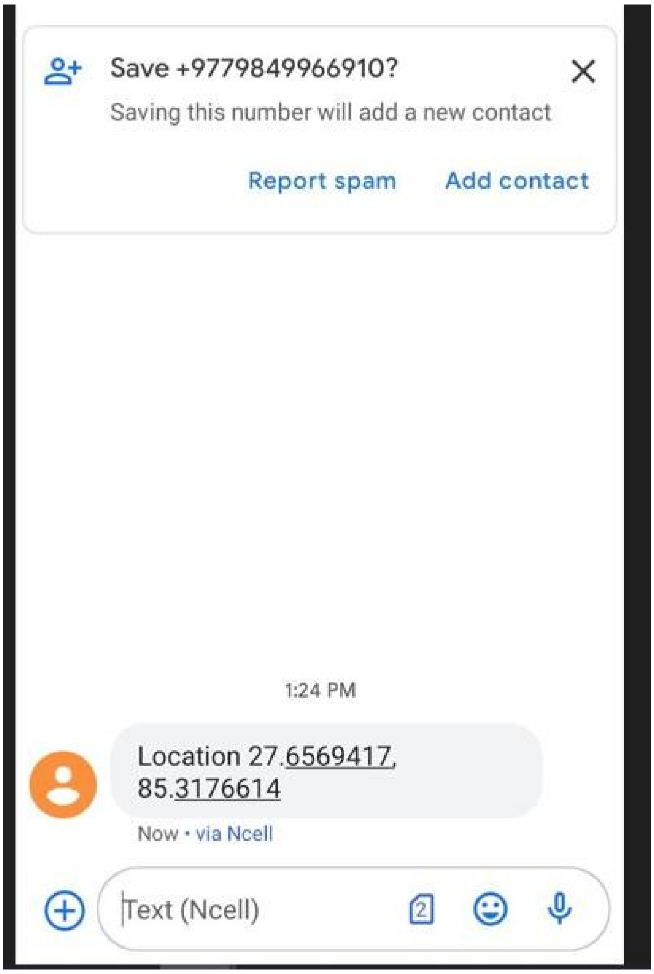

Figure 10. SMS received.

2.4 Results and Discussion

A sample of the real-time data logged by the system during simulated driving scenarios is presented in Table 2. The table captures sequential GPS coordinates (longitude, latitude, altitude), timestamp, and the corresponding driving mode classified by the MPU-6050 sensor logic. Figures 8 and 9 illustrate the Firebase Realtime Database snapshots during normal driving conditions and high disturbance (simulated accident) modes, respectively, showing how the system distinguishes and logs different states.

As shown in Table 2, the system successfully records high-precision location data (e.g., 27.65715350, 85.31742950) with an altitude resolution down to decimeters. More importantly, it demonstrates the core accident detection functionality: the 'Driving Mode' column categorizes the vehicle's state as either "Normal" or "High disturbance." The consecutive entries in Table 2 all indicate "High disturbance," which corresponds to the system's triggered state during a simulated accident event. This output directly validates that the sensor fusion algorithm can detect anomalous conditions and tag the associated spatiotemporal data accordingly.

Upon detection of a high disturbance event, the system automatically composes and sends an SMS alert containing the current GPS location to the predefined emergency contact number, as demonstrated in Figure 10.

3 Conclusions

This study presents a practical and cost-effective solution for real-time vehicle accident detection and automated alerting. By integrating the MPU-6050 sensor, GPS Neo-7m, ESP32 microcontroller, and GSM module, the system successfully detects sudden changes in vehicle orientation and speed, determines the precise accident location (latitude, longitude, altitude, date, and time), and instantly transmits this information to designated emergency contacts via SMS. The results demonstrate that the proposed system can significantly reduce the time required for accident reporting compared to conventional manual methods, which is particularly beneficial in remote and hilly regions where communication infrastructure is limited.

The key takeaway of this work is the development of a standalone, internet-independent accident detection and notification framework that is simple to deploy, reproducible, and effective for improving emergency response times. This system is expected to benefit law enforcement agencies, rescue teams, and transportation management systems by enabling quicker decision-making and accurate post-incident analysis.

While the current implementation is functional and reliable, certain limitations were observed, such as the dependency on GSM networks in areas with poor signal coverage. Future enhancements could involve satellite-based communication for SIM-less operation, advanced GSM modules for better network reliability, and PCB-based compact hardware design for faster connectivity and durability. Integrating this technology with government transportation systems could further improve safety on hazardous routes.

In summary, the project not only achieves its primary objective of real-time accident detection and reporting but also offers a scalable foundation for future research in intelligent transportation systems and IoT-based safety solutions.

Data Availability Statement

Data will be made available on request.

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This work was supported without any funding.

Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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