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Vehicle Black Box for Accident Data Storage and GPS SMS Alert Using ESP32

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Abstract - In many road accidents, help reaches the victim late because the location of the vehicle is not known and the vehicle itself keeps no record of what happened. This paper presents a low-cost Vehicle Black Box that handles both problems in one unit. An ESP32 microcontroller is the main controller of the system. An MPU6050 motion sensor detects the sudden impact of a collision, a microSD card stores the time, date and sensor readings, a Neo-6M Global Positioning System (GPS) module finds the location, and a SIM800L/SIM900A Global System for Mobile Communications (GSM) module sends that location as a Short Message Service (SMS) alert to the emergency contacts without any manual action. The paper explains the block diagram, the components, the detection method based on resultant acceleration, and the working of the complete system. The unit is compact, uses easily available modules, and can be fitted in an ordinary vehicle that has no event data recorder. The expected outcome is a faster emergency response and stored data that can be used later to study the cause of the accident.

Key Words: Vehicle Black Box, ESP32, Accident Detection, GPS, GSM, MPU6050.

1. INTRODUCTION

The number of road accidents keeps increasing, and so does the loss of life. Whether a badly injured person survives can depend on how soon someone reaches the spot. Most of the time the delay occurs because the exact place is not known, or because nobody calls for help quickly.

Aeroplanes carry a black box that records the flight. A car or a bike has nothing like that, so after a crash it is very hard to say what really caused it.

In this paper we describe a Vehicle Black Box made with the ESP32 microcontroller. When the vehicle gets hit, the motion sensor notices the impact. The Global Positioning System (GPS) module gives the position, the microSD card keeps a record, and the Global System for Mobile Communications (GSM) module sends a Short Message Service (SMS) alert to the emergency contacts, all without anybody pressing a button. We want the help to reach early and we want the data to be available for analysis later.

The main idea is simple: detection, data storage and the location alert are put together in one cheap unit built from modules that are easily available in the market. The rest of the paper is organised as follows. Section 2 reviews related work, and Section 3 gives the research gap and the problem statement. The methodology is described in Section 4 and the implementation in Section 5. Section 6 discusses the outcomes we expect. The limitations and the conclusion are given in Sections 7 and 8.

2. RELATED WORK

Accident detection and reporting has been tried by many people using embedded and Internet of Things (IoT) systems. Chaudhari et al. [1] made a smart accident detection and alert system. Priyadharshini et al. [2] developed an automated vehicle accident alert system with IoT, while Navin Kumar et al. [3] looked at how to characterise the impact of a vehicle and report the accident. A few studies from 2024 and 2025 are also close to our work. One of them detects accidents with an accelerometer, GPS and GSM and sends an SMS automatically. Another is a smart black box in which impact sensors and a data logger record the vehicle parameters before and after the crash. There is also a Raspberry Pi based system with GPS and cloud storage that improves accuracy and lets the data be seen remotely, and a tracking and emergency alert platform that reduces the response time by using instant GSM alerts.

Some earlier papers work differently. Amin and Jalil [4] and Fernandez et al. [5] watch the speed of the vehicle through GPS. If the speed falls suddenly, they take it as an accident and send the position by General Packet Radio Service (GPRS) or GSM. Pawar et al. [6] and Prabha et al. [7] use an accelerometer or a vibration sensor along with GPS and GSM, on a microcontroller or an ARM board, to send the SMS. Sarker et al. [8] send a Google Maps link to the nearest hospital and police station, using an Arduino with an accelerometer, ultrasonic sensors, GPS and GSM. Nasr et al. [9] include navigation in the reporting, and Kodali and Sahu [10] push the accident data to an IoT platform through Message Queuing Telemetry Transport (MQTT).

One thing is common in all of them. The sensor is nearly always an accelerometer or a vibration sensor, and the alert goes out through GPS and GSM. What we could not find in most of them is a record of the accident saved on the device itself. They stop once the alert is sent.

3. RESEARCH GAP AND PROBLEM STATEMENT

3.1 Research Gap

A lot of the existing systems only detect the accident and do not store the complete accident data. Some of them send an alert, but the location they give is not accurate enough. Hardly any project has detection, storage and alerting together in one system, and a compact, cheap system that does all of this is what is needed.

3.2 Problem Statement

In normal vehicles there is no proper way to record the accident data, and every minute lost in the emergency response increases the danger to the injured person. Without the data, finding the real cause of the accident is also difficult. The problem is therefore to design a smart system with the ESP32 that stores the accident information and sends an instant GPS SMS alert. The objectives are given below.

- To design a Vehicle Black Box using the ESP32.
- To detect accidents automatically using sensors.
- To store the accident data for future analysis.
- To send the GPS location by SMS as soon as an accident happens.

4. PROPOSED METHODOLOGY

4.1 Overall Methodology

The system has four parts: system setup, accident detection, data recording, and the GPS and SMS alert. The block diagram is shown in Fig. 1. The ESP32 manages every other part. The accelerometer or vibration sensor senses a sudden impact or collision, and when that happens the time, date and sensor values are stored in memory. After this, the GPS module takes the location and the GSM module immediately sends it by SMS to the emergency contacts.

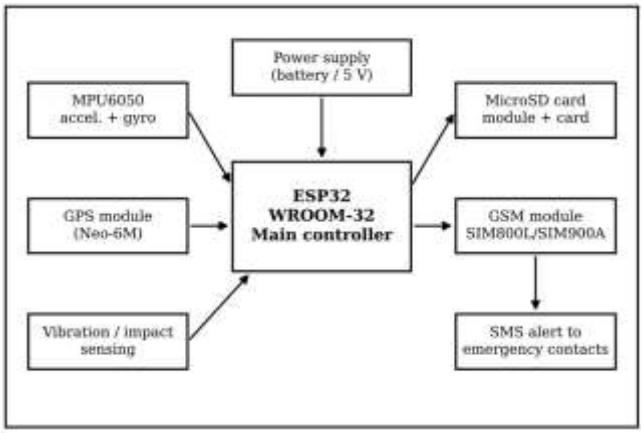

Fig -1: Block diagram of the Vehicle Black Box.

4.2 Hardware Components

The components used in this work and their purpose are given in Table 1.

Table -1: Components and their roles

Component	Role in the system
ESP32-WROOM-32 board	Main controller; reads the sensor, GPS and SD card and drives the GSM module
Neo-6M GPS module	Gives latitude, longitude, date and time
SIM800L / SIM900A GSM module + SIM card	Sends the SMS alert over the mobile network
MPU6050 sensor	3-axis accelerometer and gyroscope for detecting the impact
MicroSD card module + card	Stores the accident records
Battery or 5 V source	Power supply

4.3 Accident Detection

The MPU6050 gives acceleration values for the three axes. We combine them to get the resultant acceleration:

$$a = \sqrt{(a_x^2 + a_y^2 + a_z^2)} \quad (1)$$

Here a_x, a_y and a_z are the readings of the x, y and z axes. When the resultant acceleration is more than a fixed threshold, the system takes it as an accident:

$$a > a_{th} \quad (2)$$

The value of a_{th} has to be decided by testing. If it is too low, hard braking or a bad road will give false alerts. If it is too high, a real collision may be missed. The gyroscope reading can also be used with the accelerometer to find a sudden change in the orientation, for example when the vehicle turns over.

After an accident is detected, the ESP32 takes the GPS position, date and time and writes them to the microSD card along with the sensor values. As the record is on the card, it stays safe even when there is no network. Then the ESP32 asks the GSM module to send an SMS with the accident message and the location to the saved emergency contacts. Fig. 2 shows the full sequence.

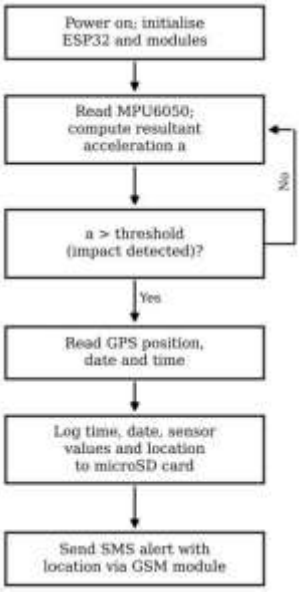

Fig -2: Operating flowchart of the system.

5. SYSTEM IMPLEMENTATION

For the hardware, the MPU6050 is connected to the ESP32 through the Inter-Integrated Circuit (I²C) bus. The Neo-6M GPS and the GSM module use the Universal Asynchronous Receiver-Transmitter (UART), and the microSD card module uses the Serial Peripheral Interface (SPI). Power comes from a battery or a regulated 5 V supply. One thing to take care of is that the GSM module draws a high current for a short time while it is sending, so the supply should be able to provide that. In the firmware, all the modules are initialised first and then the motion sensor is read again and again. When an impact is found, the record and alert steps of Fig. 2 are carried out. The connections between the ESP32 and the other modules are shown in Fig. 3.

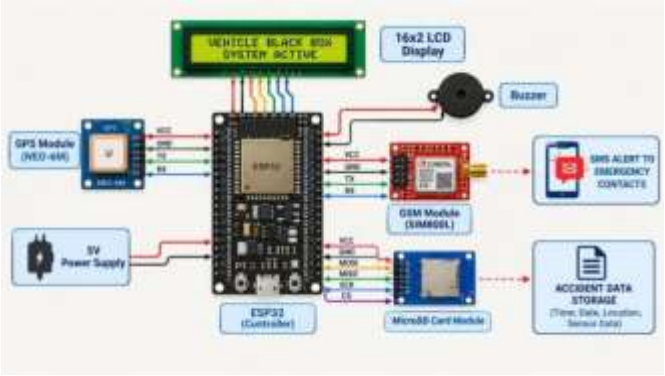

Fig -3: Circuit connection diagram of the Vehicle Black Box.

All the modules are low in cost and easy to buy. Because of this, the unit can be fitted even in ordinary vehicles that do not have an event data recorder.

6. RESULTS AND DISCUSSION

Table 2 lists what we expect from the system in each functional test. We want the accident to be detected automatically, the data to be stored safely, the GPS to give the right location, and the SMS to reach the emergency contacts soon after the accident.

Table -2: Functional behaviour expected from the system

Function	Expected behaviour
Impact detection	Alert is triggered when the resultant acceleration crosses the threshold, and not during normal driving
Data storage	Time, date, sensor values and location are saved on the microSD card
Location tracking	Current latitude and longitude are read from the GPS module
SMS alert	SMS with the location reaches the emergency contacts right after detection

Since detection, storage and alerting are all in one unit, the gap pointed out in Sec. 3 is covered. The stored records help in studying the cause of the accident, and the location SMS saves time in sending help. The project also relates to four United Nations Sustainable Development Goals: Good Health and Well-Being, because it can reduce deaths in accidents; Industry, Innovation and Infrastructure, because it uses smart technology; Sustainable Cities and Communities, because roads become safer; and Partnerships for the Goals, because it supports emergency response systems.

7. LIMITATIONS AND FUTURE WORK

7.1 Limitations

The threshold needs calibration and may have to be changed for different vehicles. GPS is weak when the sky is not clearly visible, and the SMS goes only where there is mobile network. Only one type of sensor is used for detection. Also, we have not yet measured quantities such as the detection delay or the number of false alerts.

7.2 Future Work

The next step is to test the system on the road and measure how well it works. After that, we can add a heart-rate sensor to know the condition of the person inside, send the accident data to a central server through Wi-Fi or mobile data, make an automatic call to the family, and use a Raspberry Pi if more processing power is required.

8. CONCLUSIONS

We have presented a Vehicle Black Box using the ESP32. The MPU6050 detects the accident, the data is saved on a microSD card and the GPS location is sent as an SMS by the GSM module. The cost is low and everything is in one unit, so it can help the rescue to start sooner and help in studying the accident later. Road testing and the improvements mentioned above are still to be done before the system can be used on a large scale.

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