Automobile Black Box System for Accident Analyzation

[1]Vedant Ghike, [2]Sahil Ghuge, [3]Dhruv Akhare, [4]Kshitij Deshmukh, [5]Roshan Shingare, [6]Om Awaghad, [7]R.M.Gharat.

[1,2,3,4,5,6] Students, Electronics Engineering, [7]HOD, Electronics Engineering.

Dr. Panjabrao Deshmukh Polytechnic, Amravati, Maharashtra, India.

I. ABSTRACT: -

Road accidents are a major cause of injuries and fatalities, and determining their exact cause is often difficult due to the lack of reliable recorded data. To address this issue, an Automobile Black Box System using ESP32 and Raspberry Pi 4 is proposed to monitor vehicle conditions. Sensors such as MPU6050, vibration sensor, alcohol sensor, flame detector, and GPS module continuously track parameters like acceleration, vibration, fire, alcohol presence, and location. The ESP32 processes the sensor data and sends it to the Raspberry Pi 4 through UART communication when abnormal conditions are detected. The Raspberry Pi 4 records video footage and stores sensor and location data on an SD card for accident analysis and improving road safety.

Keywords - Raspberry pi 4, Automobile Black Box, Accident Analysis, Alcohol Sensor, GPS Module.

II. INTRODUCTION

Road accidents are a major global concern due to the rapid growth in vehicle usage and increasing traffic density. Factors such as overspeeding, reckless driving, alcohol consumption, and poor road conditions significantly contribute to the rising number of accidents, often resulting in serious injuries and fatalities. In many cases, the absence of immediate accident information and delayed emergency response further increases the severity of the situation. To address this issue, modern vehicle technologies such as Event Data Recorders (EDR) and automobile black box systems have been introduced to record important vehicle parameters during accidents and assist in accident investigation and analysis. These systems help authorities understand the causes of accidents and improve road safety measures [5].

Despite these developments, many vehicles still lack efficient systems capable of automatically detecting accidents and recording critical information at the time of the incident. In most accident situations, emergency services are not notified immediately, and important evidence such as vehicle condition, accident cause, and environmental conditions may be lost. This creates difficulties for investigators in determining the exact cause of accidents and delays rescue operations. Therefore, there is a strong need for an intelligent monitoring system that can automatically detect accidents, record essential data, and provide real-time alerts to improve response time and accident analysis [2].

The development of an automobile black box system is highly significant as it enhances vehicle safety and supports effective accident investigation. By integrating multiple sensors, GPS tracking, and video recording technology, the system can continuously monitor the vehicle environment and detect abnormal conditions such as gas leakage, fire, or sudden vehicle tilt indicating an accident. The system can also store video evidence and provide accurate location information, which helps emergency responders quickly reach the accident site and assists authorities in understanding the accident scenario. Such technologies can contribute significantly to improving road safety and preventing future accidents [1].

The main objective of this research is to design and implement an Automobile Black Box System for Accident Analyzation that can monitor vehicle conditions and detect accidents automatically. The system integrates sensors such as the MQ gas sensor, flame sensor, and MPU6050 accelerometer to detect abnormal events, while a GPS module is used to obtain the real-time location of the vehicle. A camera module records video footage to act as a black box recording system. Additionally, the system aims to provide timely alerts during accidents, enabling faster emergency response and improving the efficiency of accident monitoring and analysis.

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III. LITERATURE REVIEW

Researchers have been working on different ideas to make automobile black-box systems safer and more useful.

Tallapaneni Narendra et al.(2021) describe in their paper *"Automobile Black Box System for Accident and Crime Analysis"* a practical black- box unit for cars that records speed, GPS location and other sensor data, encrypts the information to prevent tampering, and automatically sends a text alert with the vehicle's position whenever a crash is detected. [1]

Aleesha Navas et al. (2024) present *"IoTBased Accident Detection Systems – A Review,"* which surveys many internet-of- things solutions that use accelerometers, cameras, and smartphone sensors to identify accidents, classify their severity, and quickly notify emergency services, showing how IoT can shorten rescue time and save lives [2]

Roshik Naga Sai Patibandla et al.(2025) in *"Evaluating Driver Perceptions of Integrated Safety Monitoring Systems for Alcohol Impairment and Distraction"* investigate how drivers feel about in-vehicle monitoring such as eye-tracking or passive breath-alcohol checks, finding that people like nonintrusive systems but remain concerned about privacy, data storage, and false alarms [3]

Praful Raman et al. (2025) propose in *"Car Accident & Alcohol Detector & Recorder Blackbox"* an integrated safety device that joins a breath-alcohol sensor with accelerometers, gyroscopes, and GPS to detect crashes, block the engine if the driver is over the legal limit, store all pre- and post-accident data securely, and optionally back it up to the cloud for later investigation. [4]

Patibandla et al. (2025) examined integrated safety monitoring systems that detect alcohol impairment and driver distraction. Their study highlighted that while non-intrusive systems such as eye-tracking are preferred, drivers expressed concerns about privacy, data handling, and system reliability. Trust in system accuracy strongly influenced user acceptance, suggesting that transparency and local data processing are essential for adoption[7]

Monika et al. (2023) proposed a car black box system similar to aircraft recorders, designed to capture pre- and post- accident data using IoT-based sensors. The system incorporates GPS for location tracking and GSM for alerts, which assists emergency response teams and insurance investigations. The black box also monitors vehicle parameters such as braking and speed, contributing to accident analysis and prevention[8]

Shubham et al. (2021) presented a comprehensive survey on IoT-based automatic accident detection approaches. The study compared methods including smartphone sensors, GSM/GPS modules, vehicular ad hoc networks (VANET), and machine learning algorithms. While these technologies improve detection speed and accuracy, issues such as network reliability, false alarms, and cost of deployment remain critical challenges[9]

Several studies within the IoT accident detection domain emphasize combining machine learning with multiple sensor inputs. For instance, vibration sensors, accelerometers, alcohol detectors, and GPS/GSM modules are often integrated to reduce false positives and provide accurate accident location data. Such hybrid systems demonstrate improved accident response times but require optimization to handle environmental variability and reduce system complexity.

IV. PROPOSED METHODOLOGY

The proposed Automobile Black Box System for Accident Analyzation is designed to monitor vehicle conditions, detect accidents automatically, and record evidence for further investigation. The system integrates ESP32, multiple sensors, GPS module, motor driver, Raspberry Pi 4, camera module, and SD card storage to create an intelligent accident monitoring system.

The architecture consists of two main units:

1. Sensor Monitoring and Accident Detection Unit (ESP32)
2. Data Recording and Storage Unit

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(Raspberry Pi 4)

The ESP32 microcontroller continuously reads data from multiple sensors such as the MPU6050 accelerometer, alcohol sensor, flame detector, vibration sensor, and GPS module. These sensors monitor the vehicle environment and detect abnormal conditions.

- The MPU6050 detects sudden tilt, acceleration, or rollover of the vehicle.
- The vibration sensor detects collision impact.
- The alcohol sensor checks for alcohol presence in the driver environment.
- The flame detector detects fire inside the vehicle.
- The GPS module provides real-time location coordinates.

If any abnormal condition or accident is detected, the ESP32 processes the data and activates the L298N motor driver to stop the motor in the prototype system. At the same time, the ESP32 sends accident data to the Raspberry Pi 4 using UART communication and internet connectivity. The Raspberry Pi 4 acts as the black box recording system. It is connected to a camera module and SD card, which continuously records video footage and stores it in the SD card. When accident data is received from ESP32, the Raspberry Pi stores the corresponding video footage and sensor data. This recorded data can later be used for accident investigation and analysis. By combining sensor monitoring, accident detection, location tracking, and video recording, the proposed system provides an efficient solution for improving vehicle safety & accident analysis.

Block Diagram

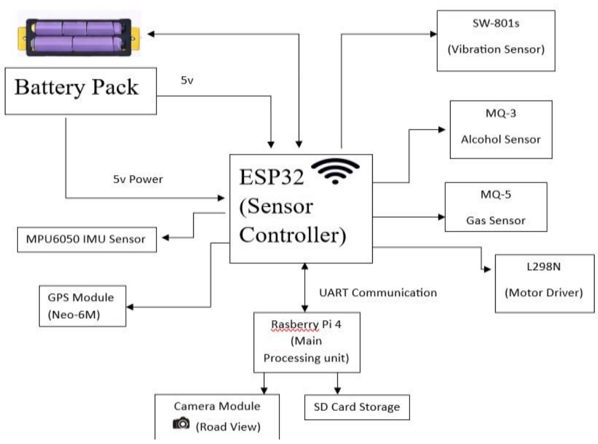

Fig.1:-Block Diagram of Automobile Black Box System

The block diagram of the Automobile Black Box System for Accident Analyzation illustrates the interaction between sensors, processing units, and recording modules used in the system. Various sensors such as the MPU6050 accelerometer and gyroscope, alcohol sensor, flame detector, and vibration sensor are connected to the ESP32 microcontroller, which continuously monitors vehicle conditions and detects abnormal events like sudden impact, fire, or alcohol presence. The GPS module provides real-time location data of the vehicle. When the ESP32 detects an accident or unsafe condition, it processes the sensor information and communicates the accident data to the Raspberry Pi 4 through UART communication and internet connectivity. The Raspberry Pi, which is connected to a camera module and SD card, records video footage and stores accident-related data, functioning as the automobile black box system. Additionally, the motor driver (L298N) is used to control the motor in the prototype vehicle and can stop the motor during critical conditions. This integrated system enables continuous monitoring, accident detection, location tracking, and video recording for effective accident analysis.

Components:-

1. MQ-5 Gas Sensor

Fig.2:-MQ-5 Gas sensor

The MQ-5 sensor detects LPG, methane, and other combustible gases. It operates on the principle of change in resistance when exposed to gas concentration. When Alcohol levels exceed the predefined threshold, the sensor outputs a HIGH signal to ESP 32, triggering an emergency event.

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2. Flame Sensor

Fig.3:-Flame sensor

The flame sensor detects infrared radiation emitted by fire in the wavelength range of 760 nm–1100 nm. It provides digital output for quick detection. Upon detecting fire, the system immediately initiates safety protocols.

3. MPU6050 Accelerometer & Gyroscope

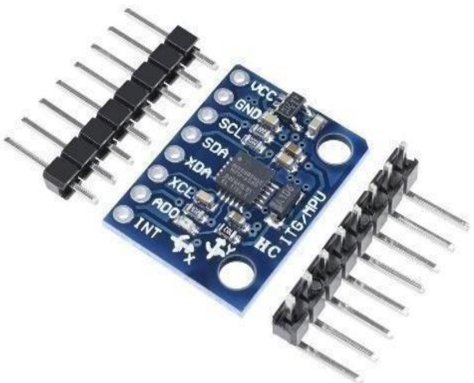

Fig.4:-MPU6050

The MPU6050 is a 6-axis motion tracking device. It measures acceleration along X, Y, and Z axes. Sudden acceleration spikes beyond threshold values indicate collision or accident. Data is transmitted via I2C communication.

4. Neo-6M GPS Module

Fig.5:-Neo-6M GPS Module

The Neo-6M module provides real-time latitude and longitude coordinates. It communicates via UART protocol and enables the system to send precise location details during emergencies.

5.Motor Driver(L298N)

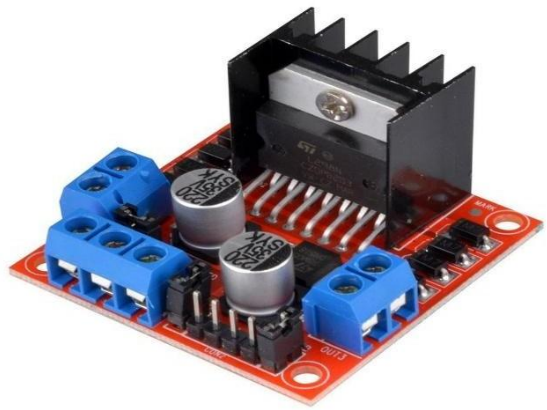

Fig.6:-Motor Driver L298N

The motor driver controls the motor in the prototype system and can stop the motor when an accident or abnormal condition is detected.

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6.Camera Module

Fig.7:Camera Module

The camera module is connected to the Raspberry Pi 4 and is used to continuously record video footage of the vehicle surroundings. It captures high-resolution video and stores it in the SD card in short segments. During an accident, the recorded footage acts as a digital black box record, which can be used as visual evidence for accident analysis and investigation.

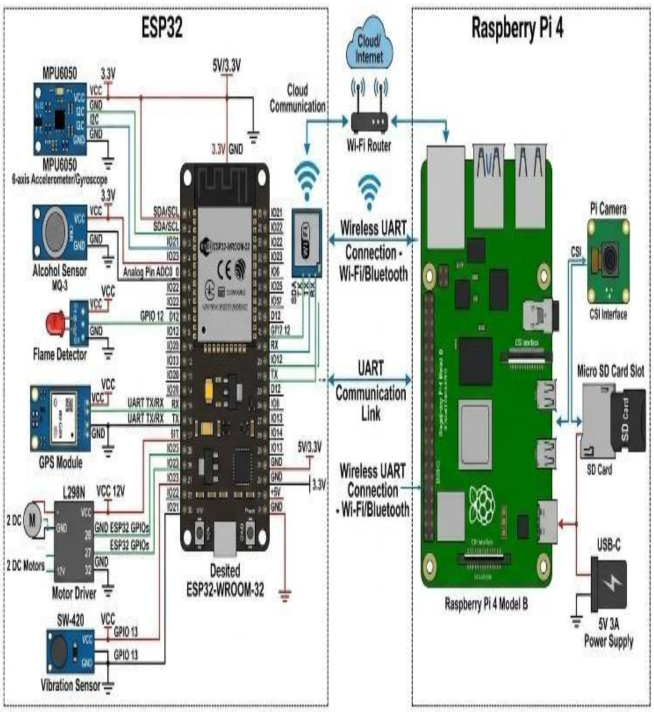

Fig.8:-Circuit Diagram of Automobile Black Box System for Accident Analyzation

The circuit diagram of the Automobile Black Box System for Accident Analyzation shows the connection between sensors, processing units, and recording components used in the system. In this circuit, the ESP32 microcontroller acts as the main controller that receives data from different sensors. The MPU6050 accelerometer and gyroscope is connected to the ESP32 through the I²C communication interface and is used to detect sudden acceleration or vehicle tilt during an accident. The vibration sensor is connected to a GPIO pin of the ESP32 and detects strong vibrations caused by collision or impact.

The alcohol sensor is connected to the ESP32 to monitor the presence of alcohol in the driver's environment, while the flame sensor detects fire or high heat conditions that may occur after an accident. The GPS module is also interfaced with the ESP32 through serial communication to provide the real-time location of the vehicle. Additionally, the L298N motor driver is connected to the ESP32 to control the prototype vehicle motor and stop the motor during abnormal conditions.

The ESP32 communicates with the Raspberry Pi 4 using UART communication (TX and RX pins) to transmit accident-related sensor data. The Raspberry Pi 4 acts as the data processing and recording unit. A camera module is connected to the Raspberry Pi through the CSI interface, which continuously records video footage. An SD card is used with the Raspberry Pi to store recorded videos and sensor data. This circuit enables the system to detect accidents, collect important information, and store it for later accident analysis.

V. RESULT

Fig.9:Result

The proposed Automobile Black Box System for Accident Analyzation was successfully designed and implemented using ESP32, Raspberry Pi 4, and various sensors. The system was able to continuously monitor important vehicle parameters such as sudden acceleration, vibration, alcohol presence, and fire detection through sensors like MPU6050, vibration sensor, alcohol sensor, and flame detector. During experimental testing, the sensors effectively detected abnormal conditions such as sudden impact or excessive vibration that may indicate an accident situation.

The ESP32 microcontroller collected and processed the sensor data in real time and transmitted the relevant information to the Raspberry Pi 4 through UART communication. The Raspberry Pi 4 successfully activated the camera module to record video footage during operation and stored the video along with sensor data in the SD card. The GPS module also provided accurate location information, which can help in identifying the exact accident location.

The overall testing results demonstrate that the system is capable of detecting accident-related events and recording important information such as sensor readings, location data, and video evidence. This stored information can be used for accident investigation, safety analysis, and improving emergency response systems. The system operated reliably during testing and proved to be an effective prototype for an automobile black box system.

VI. CONCLUSION

In conclusion, the Automobile Black Box System for Accident Analysation provides an effective approach to improve road safety and support accident investigation. The system focuses on recording important vehicle and environmental data that can help in understanding the circumstances of an accident. By collecting and storing critical information, the system can assist investigators, insurance agencies, and authorities in identifying the causes of accidents more accurately.

The implementation of such systems in vehicles can significantly contribute to improving transparency and accountability in road accidents. It can also help in developing better safety measures and policies to reduce accident rates. Overall, the automobile black box system serves as a valuable tool for accident analysis, data recording, and enhancing overall vehicle safety, making it a promising solution for future intelligent transportation systems.

Future scope

The proposed Automobile Black Box System for Accident Analyzation using ESP32 and Raspberry Pi can be further improved by integrating advanced technologies such as cloud data storage, artificial intelligence for accident prediction, and automatic emergency alert systems. Additional sensors and high-resolution cameras can also be incorporated to capture more detailed accident information. These enhancements will make the system more reliable and efficient for real-time accident monitoring and analysis. With further development and testing, the system can be implemented as a practical safety solution in modern vehicles to improve road safety and accident investigation.

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