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IoT-Based Black Box System Using CAN Protocol for Automobiles

[1]Tejasvi Nigade, [2]Dr. Kanchan Vaidya

[1]Student, Electronics and Telecommunication Engineering, Ajeenkya D. Y. Patil School of Engineering (SPPU), Pune, Maharashtra, India

[2]Professor, Electronics and Telecommunication Engineering, Ajeenkya D. Y. Patil School of Engineering (SPPU), Pune, Maharashtra, India

***Abstract* - Road accidents remain one of the major causes of fatalities and property loss, primarily due to delayed response, lack of evidence, and unmonitored driver behavior. This project presents an IoT-enabled Car Black Box System designed to enhance vehicle safety, monitor driving conditions, and assist post-accident investigation. The system integrates Raspberry Pi 3B+ with various sensors such as ADXL335 accelerometer, HC-SR04 ultrasonic sensor, MQ-3 alcohol sensor, and limit switch to continuously collect real-time data related to vehicle motion, distance, and driver condition. In case of an accident or abnormal event, the system automatically triggers alerts through a buzzer and restricts vehicle movement via the L298N motor driver. A secondary Arduino Nano unit handles GPS tracking, GSM communication, and on-board display for immediate status updates. The recorded data is transmitted to cloud servers through an ESP-01 IoT module, while MCP2515 supports CAN-based vehicle data logging. The system functions as a cost-effective black box, providing crucial evidence during accidents, enabling emergency response, and supporting analysis for improved road safety.**

Keywords: Car Black Box, Raspberry Pi 3B+, Arduino Nano, Accident Detection, GPS Tracking, GSM Alert, IoT Monitoring, Driver Safety, CAN Bus, ADXL335, Alcohol Detection.

I. INTRODUCTION

Road transportation plays a vital role in the economic and social development of any nation. With the rapid increase in the number of vehicles on roads, the frequency of accidents has also escalated, leading to significant loss of life, injuries, and property damage. According to various global safety reports, a major cause of accident-related fatalities is delayed emergency response and insufficient availability of real-time data to determine the cause of the incident. In most cases, there is no reliable system to monitor critical driving conditions, analyze vehicle parameters during accidents, or document evidence for post-event investigation. Unlike aviation, where black box systems have long been used to record flight data, commercial automobiles generally lack such integrated accident-data monitoring systems. This creates a crucial need for an intelligent, real-time, automated vehicle monitoring and logging solution to enhance safety and accountability on roads.

A Car Black Box System is designed to continuously collect and store data related to vehicle status, driver condition, and environmental parameters, serving as a digital witness in case of road accidents. The system can provide critical information such as vehicle speed, impact force, alcohol detection, obstacle distance, and location coordinates, which can significantly aid authorities, insurance agencies, and investigators in identifying the causes of accidents. Modern advancements in embedded systems, Internet of Things (IoT), and microcontroller-based communication have made it possible to design low-cost, compact, and highly efficient automotive black box solutions.

In this project, a smart Car Black Box system is developed using Raspberry Pi 3B+ as the primary processing unit along with Arduino Nano as a co-controller for sensor interfacing and communication handling. Multiple sensors are integrated to collect real-time data: ADXL335 accelerometer for impact and tilt detection, HC-SR04 ultrasonic sensor for distance measurement, MQ-3 alcohol sensor for driver sobriety analysis, and a limit switch for immediate collision detection. The system further uses an L298N motor driver and DC motor to simulate vehicle control actions during emergency conditions. To enhance connectivity and data access, the ESP-01 IoT module is utilized for cloud communication, enabling remote monitoring and data logging. Additionally, the MCP2515 CAN module allows capturing communication from vehicle electronic systems, enhancing the practicality of the design for real automobile integration.

The system incorporates GPS and GSM modules to ensure timely response during critical events. The GPS module tracks the real-time position of the vehicle, while the GSM module transmits alerts containing accident details and

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coordinates to registered contacts or emergency services. The recorded data is displayed to the driver through a 16x2 LCD display, enabling immediate feedback related to alcohol detection, obstacle alerts, and general system status. By combining processing capability, sensor integration, IoT connectivity, and communication mechanisms, the proposed system mimics the functionality of advanced automotive diagnostic and safety devices found in modern intelligent transport systems.

This prototype aims not only to serve as an accident analysis tool but also as a preventive safety system. Continuous monitoring of driver behaviour, environment, and vehicle conditions helps identify and mitigate risks before they escalate into accidents. Such systems can significantly reduce road fatalities, especially when deployed in public transport, commercial fleets, and emergency vehicles. Additionally, the stored event data can assist in insurance claim verification, legal evidence submission, and analytical research to improve road safety policies.

Overall, the Car Black Box system proposed in this project provides a cost-effective, reliable, and scalable solution toward safer and smarter transportation. The integration of embedded hardware, wireless communication, and IoT monitoring establishes a foundation for future developments in intelligent vehicular systems, contributing to the vision of connected and autonomous mobility.

II. LITERATURE REVIEW

Ramane, Ghode, Avhare, and Raut presented the paper *"Car Accident & Alcohol Detector & Recorder Blackbox"* published in the *International Journal of Research Publication and Reviews (IJRPR)* in 2025 [1]. The authors developed an integrated vehicle black box system capable of detecting accidents and alcohol consumption using sensors such as accelerometers, gyroscopes, GPS, and MQ-3 alcohol sensors. The system supports real-time data logging and cloud storage, enabling post-accident investigation and vehicle immobilization under unsafe driving conditions. However, the study highlights challenges related to privacy concerns and dependency on continuous internet connectivity.

Chavan, M. G. V., and Bhalerao proposed *"Vehicle Black Box"* in the *International Journal of Advanced Engineering and Management (IJAEM)* in 2022 [2]. Their work focused on a CAN-enabled accident monitoring system using the STM32F407VG microcontroller integrated with alcohol sensors, GPS, and AWS cloud services. The system demonstrated accurate crash detection and alcohol monitoring, though it lacked camera-based evidence and suffered from limited GPS precision.

Kiranmayee, Patra, and Anand introduced *"Wireless Blackbox for Cars Using Sensors and GPS Module"* published in the *Journal of Xi'an University of Architecture & Technology* in 2022 [3]. The authors designed a low-cost wireless black box using Arduino Uno, GSM, GPS, accelerometer, vibration, temperature, and alcohol sensors. The system efficiently detected accidents and transmitted GPS-based alerts to emergency contacts, but it was limited by restricted data storage and absence of cloud integration.

Jadhavar *et al.* presented *"Car Black Box System for Accident Analysis Using IoT"* in *JETIR* in 2025 [4]. Their work proposed an IoT-based accident detection system using Arduino Uno integrated with GSM, GPS, vibration, and alcohol sensors. The system reliably detected crash events and transmitted alerts via GSM; however, it did not include cloud connectivity or data visualization tools for long-term analysis.

Madihalli *et al.* published *"Wireless Black Box System for Vehicles"* in the *International Journal of Engineering Research* in 2020 [5]. This work focused on recording vehicle parameters during accidents using GPS, GSM, and accelerometer sensors. While the system enabled SMS alerts and local data logging, it lacked remote monitoring and advanced analytics.

Jain *et al.* conducted a comprehensive review titled *"Survey on Vehicle Black Box"* published in *IJRPR* in 2023 [6]. The paper analyzed various black box architectures, including Event Data Recorders, IoT-based systems, and machine learning approaches. The authors identified key challenges such as high cost, lack of standardization, and insufficient real-world testing, though no experimental implementation was presented.

Khayum *et al.* published *"Vehicle Black Box System for Accident Analysis Using IoT"* in *IJCRT* in 2025 [7]. The study introduced a NodeMCU-based IoT system integrating GSM, GPS, vibration, and temperature sensors. The proposed approach improved detection accuracy and reduced false positives but faced issues related to battery life and GSM signal reliability.

Josephinshermila *et al.* proposed *"Accident Detection Using Automotive Smart Black-Box Based Monitoring System"* in *Measurement: Sensors* in 2023 [8]. Their IoT-based system utilized Arduino Mega, ZigBee, GSM, GPS, and multiple sensors to achieve real-time accident reporting. The system demonstrated up to a 29% improvement in detection accuracy, though increased complexity and cost limited large-scale deployment.

Chandorkar *et al.* published *"Vehicle Blackbox"* in *IJRPR* in 2023 [9]. The authors developed a low-cost ESP32-

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based black box integrated with GSM, GPS, DHT11, and MQ-3 sensors along with an Android application. Real-time vehicle data logging and cloud upload were achieved, but system performance was heavily dependent on network availability.

Durga Prasad *et al.* presented *"Black Box for Automobiles"* in the *Journal of Engineering Sciences* in 2023 [10]. Their system focused on accident detection, fire sensing, and alcohol monitoring using Arduino Mega, MEMS sensors, GSM, and GPS. Although the system provided effective SMS alerts, it lacked IoT-based analytics and cloud storage.

Teke *et al.* introduced *"Smart Vehicle Black Box"* in *IJRESM* in 2021 [11]. The system incorporated RFID-based driver identification, alcohol detection, GPS, and GSM modules using an AT89S52 microcontroller. While effective for basic monitoring, the use of an outdated controller limited memory and scalability.

Patil *et al.* published *"Vehicle Black Box System"* in *IJRPR* in 2023 [12], focusing on accident data recording and reconstruction for insurance investigations. The system employed ATmega32A, EEPROM, GPS, GSM, and vibration sensors. However, it did not support IoT connectivity or live data access.

Ali and Khan presented *"Implementation of RFID and NFC for Public Transit Fare Automation"* in the *Journal of Transportation Engineering and Technology* in 2021 [13]. Although not directly related to accident detection, the paper demonstrated the effectiveness of RFID and NFC technologies in automated transport systems.

Kim and Lee proposed *"IoT-Based Vehicle Accident Detection and Emergency Response System"* published in *IEEE Transactions on Intelligent Transportation Systems* in 2021 [14]. Their system integrated sensors, GSM, cloud servers, and machine learning algorithms to enable rapid accident detection and emergency response, though the solution required expensive hardware.

Zhang and Wang published *"Cloud-Based Vehicle Monitoring and Safety Alert System Using IoT"* in the *International Journal of IoT Applications* in 2020 [15]. The system focused on real-time vehicle tracking and safety alerts using cloud servers and IoT nodes, with latency being a major limitation.

Monika *et al.* introduced *"Car Black Box System for Accident Analysis Using IoT"* in *IJARSCT* in 2023 [16]. The system employed a PIC microcontroller with GPS, GSM, vibration, and humidity sensors and transmitted alerts via Bluetooth, but lacked web-based cloud integration.

Lakshmi *et al.* published *"Wireless Blackbox for Cars Using Sensors and GPS Module"* in *IJRASET* in 2024 [17]. Their Arduino-based system collected real-time accident data using MEMS, alcohol, and GPS sensors, though GSM delays affected reliability.

Thanzeel *et al.* proposed *"Vehicle Black Box System"* in *International Journal of Scientific Research and Technology* in 2025 [18]. The system integrated multiple IoT sensors to enable real-time monitoring and automatic alerts, but exhibited high power consumption.

Kumar *et al.* presented *"AI-Enabled Vehicle Accident Detection and Alert System"* in *IJSRET* in 2024 [19]. The study integrated machine learning models with accelerometers and GPS to improve accident severity prediction, at the cost of increased computational complexity.

Reddy *et al.* published *"IoT-Enabled Smart Black Box for Vehicles"* in *IJESC* in 2024 [20]. Their system provided real-time vehicle monitoring through a cloud dashboard and improved emergency response, though stronger encryption and power backup were needed.

Gupta *et al.* proposed *"Low-Cost IoT-Based Vehicle Black Box"* in *IJAER* in 2024 [21]. The work focused on affordability for developing regions using NodeMCU and GSM modules, but omitted mobile applications and AI features.

Patel *et al.* introduced *"Blockchain-Based Data Integrity for Vehicle Black Box Systems"* in *IJSREM* in 2023 [22]. Their approach enhanced data integrity and trust using blockchain technology, though latency and system complexity increased.

Rodriguez *et al.* published *"Fleet Black Box for Driver Behavior Monitoring"* in *IJRITCC* in 2023 [23]. The system focused on fleet safety and driver performance monitoring using cloud analytics, raising concerns regarding driver privacy.

Sutar *et al.* presented *"Vehicle Black Box and Security System Using Microcontroller"* in 2023 [24], proposing a simple ATmega32-based system integrating IR and ultrasonic sensors for data logging and vehicle security, with limited connectivity.

Chavan *et al.* published *"Study of Smart Black Box for Automobiles"* in 2025 [25], proposing a smart black box using ESP12E NodeMCU, MQ-3, GPS, vibration sensors, and a camera module. The system supported cloud storage via ThingSpeak but required high-speed internet.

Deshmukh published *"Car Black Box System"* in 2022 [26], presenting a Raspberry Pi-based system capable of

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recording video, temperature, humidity, and motion data. The system relied on SD card storage and lacked IoT-based data upload.

Finally, Garcia-Barrientos *et al.* published *"Design and Implementation of a Car's Black Box System Using Raspberry Pi and 4G Module"* in 2022 [27]. The proposed system captured audio, video, GPS, and ECU data using a 4G module and graphical interface, offering comprehensive accident evidence at the expense of high hardware cost.

III. RESEARCH GAP

Although several automotive black box systems and accident detection technologies have been developed in recent years, most existing solutions focus primarily on either real-time alert generation or basic data logging, rather than providing a comprehensive forensic event recording system. Many systems rely mainly on GPS and GSM modules but lack multi-sensor fusion capabilities, making them less effective in accurately distinguishing between minor disturbances and actual collisions. Current systems also rarely integrate CAN bus data to extract internal engine parameters and airbag deployment information, which are essential for post-accident investigation. Furthermore, conventional accident detection mechanisms rely on predefined threshold values, which may not adapt effectively to variations in road terrain, vehicle type, or impact angle, resulting in false positives. Cloud integration is implemented in limited systems, and most lack encrypted data transmission and offline storage redundancy, compromising reliability during network failures. Additionally, existing solutions often do not support automated emergency communication with real-time vehicle coordinates and lack a unified display and reporting interface for live monitoring. Therefore, there is a need for a robust and intelligent black box architecture that integrates multiple sensors, IoT connectivity, CAN bus data, and emergency communication modules to ensure accurate accident detection, secure data logging, and timely rescue response.

IV. PROBLEM STATEMENT

Road accidents continue to be a major cause of fatalities, yet most vehicles lack an integrated system capable of accurately detecting collisions, recording critical pre- and post-impact data, and automatically alerting emergency services. Existing vehicle monitoring systems primarily focus on GPS tracking or basic impact sensing and often fail to differentiate between minor vibrations and severe crashes due to limited sensor integration and threshold-based detection methods. Additionally, crucial vehicular parameters such as engine diagnostics, vehicle orientation, and driver condition are rarely captured in real time, leading to insufficient evidence for forensic accident analysis. The absence of automated location-based emergency communication further delays medical assistance, increasing casualty rates. Therefore, there is a need for a multi-sensor, IoT-enabled automotive black box system that can reliably detect accidents, log accurate vehicular data, and transmit alerts to emergency responders with real-time GPS coordinates to improve safety and post-incident investigation.

V. OBJECTIVES

- **To design and implement an onboard black box system** capable of continuously recording critical vehicular data such as speed, GPS coordinates, acceleration, time, and sensor readings.
- **To enable real-time accident detection** using sensors like accelerometer, gyroscope, and vibration modules to identify collision impact and trigger automatic response mechanisms.
- **To provide instant emergency alert notifications** to predefined contacts or rescue services via GSM/GPS communication upon detection of an accident.
- **To create reliable data logs for post-accident analysis**, assisting investigators in reconstructing events leading to the collision.
- **To store data in non-volatile memory**, ensuring information remains intact even in severe crashes or power failure.
- **To monitor driver behaviour parameters** (such as over speeding, rash acceleration, and sudden braking) to promote safe driving habits.
- **To integrate a user interface or cloud dashboard** for retrieving historical travel and accident data for analysis.
- **To enhance road safety** by enabling quick emergency response, reducing mortality rate, and facilitating legal evidence generation.

VI. SYSTEM DESIGN

The proposed Automotive Black Box and Accident Detection System consists of two main control units, namely the Raspberry Pi 3B+ and the Arduino Nano, which work together to monitor vehicle parameters, detect accidents, and transmit emergency alerts. The Raspberry Pi serves as the primary processing unit and interfaces with multiple sensors, including an HC-SR04 ultrasonic sensor for proximity measurement, an MQ3 sensor to detect alcohol presence indicating potential drunk driving, a limit switch to sense sudden mechanical impact during collisions, and an

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ADXL335 accelerometer that measures vibration, tilt, and force to assess crash severity. The Pi processes this sensor data and connects to various modules, such as the MCP2515 CAN interface to log internal vehicle parameters from the CAN bus, a buzzer that provides audible alerts during abnormal or emergency conditions, and an ESP-01 IoT module that uploads real-time data to the cloud for remote monitoring.

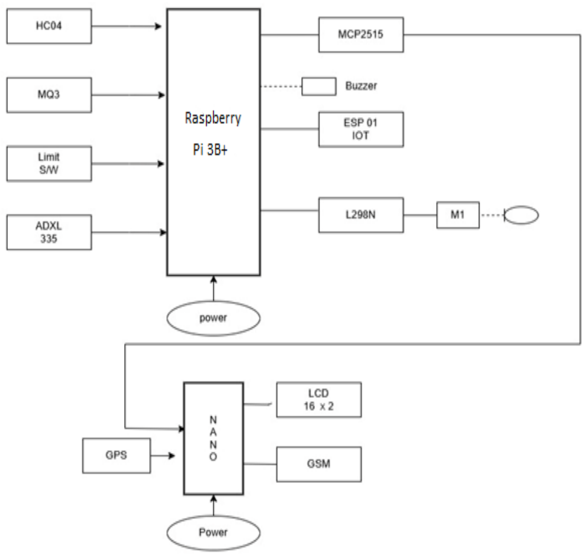

Figure 1: Block Diagram

Additionally, the Raspberry Pi drives a motor through the L298N motor driver, simulating ignition or vehicle control mechanisms within the system. The secondary control unit, Arduino Nano, handles communication and display functionalities, receiving data from a GPS module to track vehicle location, transmitting emergency messages via a GSM module to alert authorized users, and displaying system status and coordinates on a 16×2 LCD display. The system is powered through separate regulated supplies for both controllers, ensuring stable operation and continuous data logging even in the event of a crash. Together, these interconnected modules form a comprehensive vehicle monitoring and event recording platform capable of detecting accidents, logging critical data, and communicating alerts for enhanced road safety and post-accident analysis.

VII. CONCLUSION

The proposed Automotive Black Box and Accident Detection System provides an integrated solution for monitoring vehicle conditions, detecting accidents, and recording critical data for post-crash analysis. By utilizing Raspberry Pi along with multiple sensors such as the ADXL335 accelerometer, HC-SR04 ultrasonic sensor, MQ3 alcohol sensor, and CAN bus interface, the system ensures accurate real-time data acquisition and analysis. The inclusion of communication modules like GSM, GPS, and ESP-01 enables automated emergency notifications, live vehicle tracking, and remote data accessibility through IoT platforms. Additionally, the Arduino Nano assists in handling dedicated display and communication tasks, thereby distributing processing load for improved efficiency. The system not only generates immediate alerts to reduce response time during accidents but also stores essential crash data for forensic investigation. Overall, this solution enhances road safety by integrating sensor-based accident detection with digital evidence logging and communication support. Future enhancements may include machine learning-based crash prediction, onboard storage encryption, and integration with government emergency networks for large-scale deployment.

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AUTHORS BIOGRAPHY

Ms. Tejasvi Nigade, Student, Electronics and Telecommunication Engineering, Ajeenkya D. Y. Patil School of Engineering (SPPU), Pune, Maharashtra, India.

Dr. Kanchan Vaidya, Professor, Electronics and Telecommunication Engineering, Ajeenkya D. Y. Patil School of Engineering (SPPU), Pune, Maharashtra, India.

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