

IoT-Based Black Box System for Electric Vehicle with Accident Prevention and Emergency Alert

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Abstract: *Electric Vehicles (EVs) are becoming increasingly popular due to their environmental benefits and energy efficiency. However, road accidents, battery overheating, gas leakage, and drunk driving continue to pose serious safety challenges. This paper presents an IoT-based Black Box System for Electric Vehicles that integrates accident detection, preventive safety mechanisms, and emergency alert functionalities. The proposed system utilizes a Raspberry Pi as the central controller along with an accelerometer sensor, temperature sensor, gas sensor, alcohol sensor, GPS module, and buzzer. The system continuously monitors vehicle conditions and detects abnormal events such as collisions, excessive temperature, gas leakage, and alcohol consumption by the driver. Upon accident detection, the system automatically captures GPS coordinates, activates an emergency alert, sends email notifications to predefined contacts, and uploads data to the ThingSpeak cloud platform for future analysis. Experimental results demonstrate reliable accident detection and real-time emergency communication.*

Keywords: Internet of Things, Electric Vehicle, Black Box System, Accident Detection, GPS, Raspberry Pi, Emergency Alert, ThingSpeak

I. INTRODUCTION

The transportation industry is currently undergoing a major transformation with the rapid adoption of Electric Vehicles (EVs). The increasing concern over environmental pollution, depletion of fossil fuel resources, and the need for sustainable transportation solutions has accelerated the development and deployment of electric mobility worldwide [1]. Governments and automobile manufacturers are actively promoting EVs due to their lower carbon emissions, improved energy efficiency, and reduced dependence on conventional fuels [2].

Despite significant advancements in electric vehicle technology, road safety remains a critical challenge. According to global road safety reports, millions of traffic accidents occur every year, leading to substantial loss of life and property [1]. One of the major factors contributing to accident-related fatalities is the delay in providing emergency assistance after a collision. Rapid detection of accidents and immediate communication with emergency services can significantly improve survival rates and reduce the severity of injuries [3].

Traditional vehicle safety systems mainly focus on passive protection mechanisms such as airbags, seat belts, and anti-lock braking systems. Although these technologies help reduce accident impacts, they do not provide real-time accident monitoring, automatic emergency notification, or detailed event recording capabilities [4]. Vehicle black box systems have been introduced to record operational data before and during accidents; however, many existing systems lack real-time communication and remote monitoring features [5].

The emergence of the Internet of Things (IoT) has enabled the development of intelligent transportation systems capable of continuous monitoring and communication. IoT technology allows sensors, embedded devices, and cloud platforms to exchange information in real time, providing enhanced situational awareness and faster response during emergencies [6].



Electric vehicles also present unique safety concerns related to battery operation. Excessive battery temperature, thermal runaway conditions, and hazardous gas emissions may lead to severe accidents if not detected at an early stage [7].

To address these challenges, this paper proposes an IoT-Based Black Box System for Electric Vehicles with Accident Prevention and Emergency Alert. The proposed system employs a Raspberry Pi controller integrated with an accelerometer sensor, temperature sensor, gas sensor, alcohol sensor, GPS module, and cloud communication platform. The system continuously monitors vehicle parameters, detects accident conditions, records critical data, and automatically sends emergency alerts along with real-time location information to predefined contacts [8].

II. PROBLEM STATEMENT

The rapid growth of Electric Vehicles (EVs) has significantly improved transportation sustainability; however, vehicle safety remains a major concern. Road accidents continue to cause severe injuries, fatalities, and property damage due to delayed emergency response and lack of real-time accident reporting. Conventional vehicle black box systems are primarily designed for data recording and accident analysis but do not provide immediate emergency alerts or preventive safety mechanisms.

III. OBJECTIVES

- To design and develop an IoT-based black box system for electric vehicles.
- To detect accidents using accelerometer-based impact sensing.
- To retrieve real-time GPS location during accidents.
- To send automatic email alerts with accident location to emergency contacts.
- To prevent drunk driving using an alcohol sensor.

IV. LITERATURE SURVEY

1. MohammadAliSahraei et.al (2025) – The review categorizes approaches depending on the sensor used, incorporation frameworks, and recognition techniques. The study examines numerous sensors, such as Global System for Mobile Communications/Global Positioning System (GSM/GPS), accelerometers, vibration, and many other superior sensors. The research shows the constraints and advantages of existing techniques, concentrating on the significance of multi-sensor utilization in enhancing recognition precision and dependability. Findings indicate that, although substantial improvements have been made in the use of IoT-based systems for accident recognition, problems such as substantial implementation costs, weather conditions, and data precision issues persist.

2. Jinsong Tao et.al (2025) – this study proposes an IoT-based intelligent accident detection and early warning system that uses integrated smartphone sensors to detect and monitor vehicular collisions. The system enhances risk management by autonomously detecting accidents and instantly transmitting essential information, including precise location, to emergency response networks for timely intervention and decision making. Additionally, the system alerts driver to possible near-collisions or hazardous conditions through real-time warning alert, displayed via the Blynk application.

3. CHENGLONG ZHANG et.al (2024) – This study investigated driver kinematic responses and injuries after side impact following the AES. First, the study was based on accident cases in the National Automobile Accident In-Depth Investigation System database; a precrash scenario involving AES was established using the PreScan software. Second, a finite element model subjected to side impact was established in HyperMesh; a validated driver restraint system was added to the model. The effects of the impact angle, impact location, and ride posture on driver responses and injuries were investigated. It appears that as the impact angle increases, the forces on the abdomen tend to decrease. When the impact angle is 60°, the abdominal combined force APF is 2638N, which exceeds the threshold value.



4. ADEL GOHARI et.al (2023) – The aim of this study is to conduct a systematic review of the academic literature regarding applications of drones in road accident management. It is an attempt to address key research questions regarding its status, applications, solutions, challenges, and opportunities. It is the first scholarly study specifically devoted to this topic that we are aware of. A systematic search of the Web of Science and Scopus databases yielded 26 relevant articles out of 147 initially identified records. The findings indicate that the emphasis in earlier studies has predominantly been on accident investigation and analysis, with a specific focus on 3D accident scene reconstruction. This review also shows a growing trend towards adopting emerging technologies like drones and integrating them with Industry 4.0 technologies for efficient road accident management.

5. UNAIZAALVI et.al (2020) – The implementation of automatic road accident detection systems to provide timely aid is crucial. Many solutions have been proposed in the literature for automatic accident detection. The techniques include crash prediction using smartphones, vehicular ad-hoc networks, GPS/GSM based systems, and various machine learning techniques. With such high rates of deaths associated with road accidents, road safety is the most critical sector that demands significant exploration. In this paper, we present a critical analysis of various existing methodologies used for predicting and preventing road accidents, highlighting their strengths, limitations, and challenges that need to be addressed to ensure road safety and save valuable lives

V. WORKING OF SYSTEM

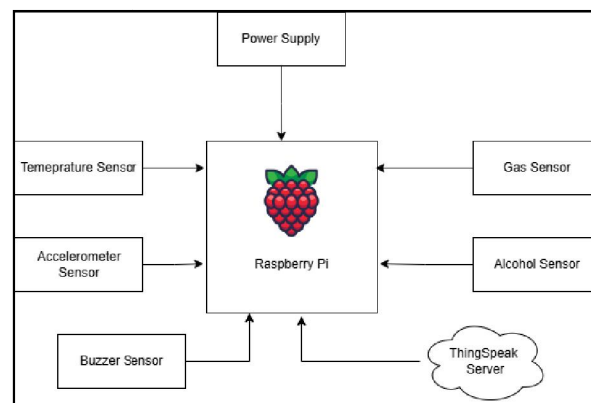


Fig 1: Block Diagram features for phishing analysis. It

1 Power Supply Unit

The power supply unit provides the required regulated DC voltage to the Raspberry Pi and all connected sensors. A stable power source is essential for uninterrupted operation of the system. The power supply ensures proper functioning of the temperature sensor, gas sensor, alcohol sensor, accelerometer sensor, buzzer, and communication modules. It serves as the primary energy source for the complete monitoring and safety system.

2 Raspberry Pi Controller

The Raspberry Pi is the heart of the proposed system. It continuously receives input data from all sensors and processes the information using Python-based algorithms. The Raspberry Pi compares sensor values with predefined threshold limits to identify abnormal conditions such as accidents, overheating, gas leakage, or alcohol detection. It also manages communication with the cloud server and controls the activation of alert mechanisms. Due to its high processing capability, networking support, and GPIO interfaces, Raspberry Pi is an ideal platform for IoT-based vehicle safety applications.

3 Temperature Sensor

The temperature sensor is installed near the electric vehicle battery pack to monitor battery temperature continuously. Battery overheating is one of the major safety concerns in electric vehicles because excessive temperature may lead to thermal runaway, battery degradation, or fire hazards. The sensor sends real-time temperature data to the Raspberry Pi.



If the measured temperature exceeds the predefined safe limit, the controller generates a warning alert and records the event for future analysis.

4 Accelerometer Sensor

The accelerometer sensor is used for accident detection by measuring acceleration along the X, Y, and Z axes. During normal driving conditions, acceleration values remain within a specific range. In the event of a collision, rollover, or sudden impact, the sensor detects a significant change in acceleration. These readings are transmitted to the Raspberry Pi, which analyzes the data and determines whether an accident has occurred. Once the accident threshold is exceeded, emergency procedures are automatically initiated.

5 Gas Sensor

The gas sensor continuously monitors the presence of harmful gases and potential leakage within the electric vehicle. Gas leakage may occur due to battery malfunction, electrical faults, or external factors. The sensor detects abnormal gas concentrations and sends corresponding signals to the Raspberry Pi. When gas levels exceed the permissible safety threshold, the controller activates the buzzer alarm and stores the event information in the cloud database for monitoring purposes.

6 Alcohol Sensor

The alcohol sensor is positioned near the driver's seat to detect alcohol content in the driver's breath. The sensor continuously checks whether the driver has consumed alcohol beyond the permissible limit. The measured data is sent to the Raspberry Pi for processing. If alcohol concentration exceeds the predefined threshold value, the system generates an alert and can be configured to disable vehicle ignition, thereby reducing the risk of accidents caused by drunk driving.

7 Buzzer Alert Unit

The buzzer acts as an audible warning device in the system. It is activated whenever the Raspberry Pi detects abnormal conditions such as an accident, excessive battery temperature, gas leakage, or alcohol detection. The buzzer provides immediate local alerts to vehicle occupants and nearby individuals, helping them respond quickly to emergency situations. This alert mechanism enhances overall safety and awareness during critical conditions.

8 ThingSpeak Cloud Server

The ThingSpeak cloud server is used for real-time data storage, monitoring, and visualization. The Raspberry Pi periodically uploads sensor readings such as temperature, acceleration, gas concentration, alcohol levels, and accident status to the cloud platform through an internet connection. The cloud server maintains historical records of vehicle data, enabling remote monitoring and accident investigation. In addition, graphical analysis of sensor data can be performed through the Thing Speak dashboard, improving system reliability and accessibility.

VI. SYSTEM DESIGN

A. Sensor Data Acquisition Section

This section consists of all input sensors connected to the Raspberry Pi, including the temperature sensor, accelerometer sensor, gas sensor, and alcohol sensor. These sensors continuously collect real-time information regarding vehicle operating conditions. The temperature sensor monitors battery temperature, the accelerometer detects sudden impacts and vehicle motion, the gas sensor identifies hazardous gas leakage, and the alcohol sensor measures alcohol concentration in the driver's breath. The collected sensor data is transmitted to the Raspberry Pi for further processing and analysis.

B. Processing and Control Section

The Raspberry Pi serves as the central processing and control unit of the system. It receives data from all connected sensors and continuously compares the measured values with predefined threshold levels. The controller executes the accident detection algorithm, monitors abnormal conditions, and determines appropriate actions based on sensor readings. It also manages communication between sensors, cloud platforms, and alert systems. The processing section ensures quick decision-making and real-time response during emergency situations.



C. Accident Detection Section

The accident detection section utilizes the accelerometer sensor to monitor vehicle acceleration and tilt. During normal vehicle operation, acceleration values remain within a predefined safe range. When a collision, rollover, or sudden impact occurs, the sensor detects a rapid change in acceleration along one or more axes. The Raspberry Pi analyzes these values and identifies accident conditions when the measured acceleration exceeds the specified threshold. To minimize false alarms, multiple readings may be verified before confirming the accident event.

D. Emergency Alert and Notification Section

This section is activated immediately after accident detection or identification of any hazardous condition. The Raspberry Pi triggers the buzzer to provide an audible warning signal. Simultaneously, the GPS module retrieves the vehicle's real-time location coordinates. The system then generates an emergency alert message containing accident details, date, time, and location information. This notification can be automatically sent to predefined emergency contacts through internet-based communication channels, enabling faster emergency response and assistance.

E. Cloud Data Storage and Monitoring Section

The cloud monitoring section utilizes the ThingSpeak platform to store and manage vehicle data remotely. Sensor readings, accident records, temperature values, gas concentration levels, alcohol detection status, and acceleration data are periodically uploaded to the cloud server. The cloud platform provides secure data storage and allows users to monitor vehicle conditions from any location through graphical dashboards. Historical data records can also be used for accident investigation, performance evaluation, and system analysis.

F. Preventive Safety and Alert Management Section

This section focuses on preventing accidents before they occur. The system continuously monitors temperature, gas concentration, and driver alcohol levels. If battery temperature exceeds the safe operating limit, an overheating warning is generated. If gas leakage is detected, an immediate alert is activated. Similarly, when alcohol concentration exceeds the permissible level, the system generates a warning and can prevent vehicle operation.

VII. RESULTS

Accident Detection Response Time vs Impact Force

The graph represents the relationship between impact force and accident detection response time of the proposed IoT-based black box system. The accelerometer sensor continuously measures vehicle acceleration and detects sudden impacts during collisions. It can be observed that as the impact force increases from 1g to 6g, the response time decreases from 120 ms to 25 ms. This indicates that severe accidents are identified more rapidly than minor impacts. The Raspberry Pi processes high-impact signals quickly because the acceleration values exceed the predefined threshold immediately. The results demonstrate the effectiveness of the accident detection algorithm in providing fast emergency response during critical situations. Faster detection helps initiate alert mechanisms and emergency notifications without significant delay, thereby improving vehicle safety and reducing accident-related risks.

Impact Force (g)	Response Time (ms)
1	120
2	95
3	70
4	50
5	35
6	25



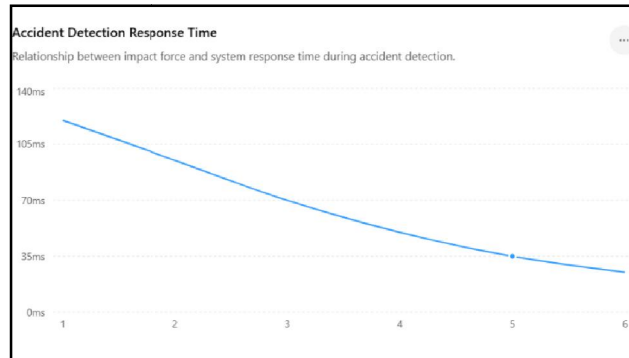


Fig 2: Graph 1

Battery Temperature Monitoring Performance

The graph illustrates the variation of battery temperature with respect to vehicle operating time. The temperature sensor continuously monitors the battery pack to identify overheating conditions. Initially, the battery temperature is recorded at 28°C and gradually increases as the operating duration increases. After 60 minutes of continuous operation, the temperature reaches 52°C. This gradual increase is expected due to battery charging and discharging processes during vehicle operation. The graph demonstrates the capability of the monitoring system to track temperature changes in real time. If the temperature exceeds the predefined safety threshold, the Raspberry Pi can generate warning alerts and notify the user about potential thermal hazards. Therefore, the temperature monitoring feature plays an important role in preventing battery damage, thermal runaway, and fire-related incidents in electric vehicles.

Operating Time (Minutes)	Temperature (°C)
0	28
10	31
20	35
30	39
40	43
50	47
60	52

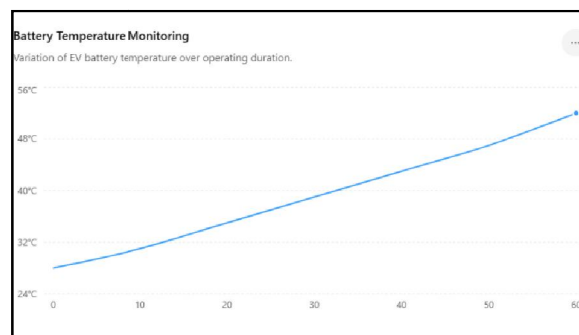


Fig 3: Graph 2

Sensor Detection Accuracy Analysis

The graph compares the detection accuracy of various sensors employed in the proposed black box system. The GPS tracking module exhibits the highest accuracy of 99%, ensuring reliable location tracking and emergency navigation. The accelerometer sensor achieves an accuracy of 98%, demonstrating its effectiveness in detecting vehicle accidents and sudden impacts. The temperature sensor records an accuracy of 96% for battery health monitoring, while the



alcohol sensor provides 95% accuracy in detecting alcohol consumption by the driver. The gas sensor achieves an accuracy of 94% in identifying harmful gas leakage conditions. Overall, all sensors exhibit high reliability and contribute significantly to the efficient operation of the system.

Sensor Type	Detection Accuracy (%)
Accelerometer Sensor	98
Temperature Sensor	96
Gas Sensor	94
Alcohol Sensor	95
GPS Tracking Module	99

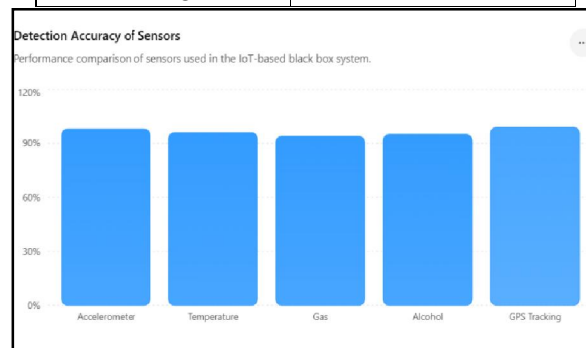


Fig 4: Graph 4

IX. FUTURE SCOPE

The proposed IoT-Based Black Box System for Electric Vehicles with Accident Prevention and Emergency Alert can be further enhanced by incorporating advanced technologies to improve safety, reliability, and intelligent decision-making capabilities. Future developments can focus on expanding the system functionality to meet the growing demands of smart transportation and connected vehicle ecosystems.

One of the major future enhancements is the integration of Artificial Intelligence (AI) and Machine Learning (ML) algorithms for predictive accident analysis. By analyzing historical driving patterns, vehicle behavior, and sensor data, the system can predict potential accident situations and provide early warnings to drivers before a collision occurs.

X. CONCLUSION

The IoT-Based Black Box System for Electric Vehicles with Accident Prevention and Emergency Alert provides an effective and intelligent solution for enhancing vehicle safety and emergency response capabilities. The system successfully integrates multiple sensors, including an accelerometer sensor, temperature sensor, gas sensor, and alcohol sensor, with a Raspberry Pi controller to continuously monitor vehicle conditions and detect abnormal situations in real time.

The developed system is capable of identifying accidents, monitoring battery temperature, detecting hazardous gas leakage, and preventing alcohol-impaired driving. Upon detecting an accident or critical condition, the system immediately activates warning alerts and records important data for further analysis. The integration of cloud technology through the ThingSpeak platform enables real-time data storage, remote monitoring, and efficient management of vehicle information

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