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Accident Detection and Vehicle Black Box System

Aditya Shimpi[1], Aditya Shirsath[2], Nikita Ekhande[3], Chetana Kurhade[4], Prof. Archana R. Sonawane[5]
Vidyarthi Griha's college of Engineering & Shrikrushna S. Dhamankar Institute of Management, Nashik, India
Department of Electronics and Telecommunication Engineering, Pune

Abstract: ***This paper presents the design and implementation of a Smart Bike Black Box System that enhances road safety through real-time monitoring and accident detection using Internet of Things (IoT) technology. The proposed system integrates an ESP32 microcontroller with multiple sensors such as a GPS module, MPU6050 accelerometer, vibration sensor, and a limit switch to monitor vehicle conditions continuously. The system transmits live data including speed, location, and acceleration to a cloud platform using Firebase Realtime Database. A multi-condition accident detection algorithm is implemented to improve accuracy and reduce false alarms. In the event of an accident, the system logs the incident and sends instant alerts along with the precise location via SMS using Fast2SMS API. The system is cost-effective, reliable, and suitable for real-world deployment, contributing significantly to improving emergency response time and reducing accident fatalities.***
Keywords: ***IoT, ESP32, accident detection, Firebase, GPS tracking, smart safety system, embedded systems.***

I. INTRODUCTION

Road accidents are a major global concern, resulting in a significant number of injuries and fatalities every year. One of the primary reasons for increased fatality rates is the delay in emergency response after an accident occurs. In many cases, victims do not receive timely medical assistance due to lack of immediate communication.

With advancements in embedded systems and IoT technologies, it is now possible to design intelligent systems capable of detecting accidents and notifying emergency services in real time. This paper proposes a Smart Bike Black Box System that continuously monitors vehicle parameters and detects accidents using a combination of sensors.

The system aims to provide real-time tracking, accident detection, and alert mechanisms to ensure quick response during emergencies. By integrating cloud computing and communication technologies, the system enhances safety and provides valuable data for analysis.

II. LITERATURE REVIEW

Several research works have been conducted in the field of accident detection and vehicle monitoring systems. Traditional systems rely on single-sensor detection mechanisms, which often result in false alarms due to road conditions such as bumps or sudden braking. Recent advancements focus on multi-sensor fusion techniques to improve detection accuracy. Systems using accelerometers and GPS modules have shown promising results; however, they still face challenges in distinguishing between normal disturbances and actual accidents. Some solutions incorporate GSM modules for alert transmission, while others use mobile applications for monitoring. However, many existing systems lack real-time Cloud integration and intelligent decision-making algorithms. The proposed system addresses these limitations by using multiple sensors, cloud-based data storage, and an efficient accident detection algorithm.

III. SYSTEM ARCHITECTURE

The proposed Smart Bike Black Box System is designed using a combination of hardware and software components that work together to monitor vehicle conditions, detect accidents, and transmit data to a cloud platform. The architecture is divided into three major layers: sensing layer, processing layer, and communication layer.

A. Sensing Layer

The sensing layer is responsible for collecting real-time data from the environment and the vehicle. It consists of multiple sensors that capture different parameters required for accurate accident detection.

The GPS module is used to obtain real-time geographical coordinates such as latitude and longitude, along with the speed of the vehicle. This information is essential for tracking the vehicle and identifying the accident location.

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The MPU6050 sensor, which is a combination of an accelerometer and gyroscope, is used to measure acceleration forces along different axes. Sudden changes in acceleration are indicative of collisions or abrupt movements.
The vibration sensor detects mechanical shocks and vibrations that occur during an impact. This helps in identifying physical disturbances that may not always be captured by acceleration data alone.
The limit switch acts as a direct collision detector. When a strong physical impact occurs, the switch is triggered, providing an additional confirmation of an accident event.

B. Processing layer

The processing layer is handled by the ESP32 MICROCONTROLLER, which acts as the central unit of the system. It collects data from all sensors and processes it in real time.
The ESP32 evaluates the sensor inputs using a predefined accident detection algorithm. The algorithm checks whether certain threshold conditions are met, such as high acceleration, presence of vibration, or activation of the limit switch.
A multi-condition logic is implemented where at least two sensor conditions must be satisfied to confirm an accident. This approach reduces false positives caused by normal road conditions like bumps or sudden braking.
The processed data is also displayed locally on an LCD screen, which shows important parameters such as speed and system status.

C. Communication layer

The communication layer is responsible for transmitting data from the system to external platforms. The ESP32 uses built-in Wi-Fi capabilities to send data to a cloud database.
The system is integrated with FIREBASE REALTIME DATABASE, where both live data and accident logs are stored. Live data includes parameters such as location, speed, and sensor readings, while accident logs contain detailed information about detected incidents.
In addition to cloud storage, the system also sends immediate alerts using the FAST2SMS API. When an accident is detected, an SMS message containing the accident details and a Google Maps Link of the location is sent to predefined contacts. This layer ensures real-time monitoring and quick communication during emergency situations.

D. Overall system operation

The overall system operates in a continuous loop where sensor data is collected, processed, and transmitted. Under normal conditions, live data is periodically updated in the cloud. When an abnormal condition is detected, the system triggers the accident detection mechanism and sends alerts instantly.
This architecture ensures reliable performance, efficient data handling, and rapid emergency response, making the system suitable for real-world deployment.
The system continuously collects data from all sensors. The GPS module provides location and speed, while the MPU6050 sensor measures acceleration. The vibration sensor and limit switch detect physical impacts.
The collected data is processed by the ESP32 microcontroller. A decision-making algorithm evaluates the sensor inputs to determine whether an accident has occurred. If an accident is detected, the system immediately sends data to the cloud and triggers alert notifications.

IV. ACCIDENT DETECTION ALGORITHM

1) Start the system
2) Initialize ESP32, sensors, and Wi-Fi connection
3) Read data from GPS module (latitude, longitude, speed)
4) Read acceleration values from MPU6050
5) Read vibration sensor status
6) Read limit switch status
7) Calculate total acceleration
8) Set trigger count = 0
9) If acceleration > threshold → increment trigger count
10) If vibration detected → increment trigger count
11) If limit switch activated → increment trigger count

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12) If trigger count ≥ 2
   a. Declare accident detected
   b. Send data to Firebase
   c. Send SMS alert with location
13) Else
   continue monitoring
14) Repeat loop

V. WORKING PRINCIPLE

The system continuously collects data from all sensors. The GPS module provides location and speed, while the MPU6050 sensor measures acceleration. The vibration sensor and limit switch detect physical impacts.

The collected data is processed by the ESP32 microcontroller. A decision-making algorithm evaluates the sensor inputs to determine whether an accident has occurred. If an accident is detected, the system immediately sends data to the cloud and triggers alert notifications.

VI. INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN SCIENCE DATA TRANSMISSION AND CLOUD STORAGE

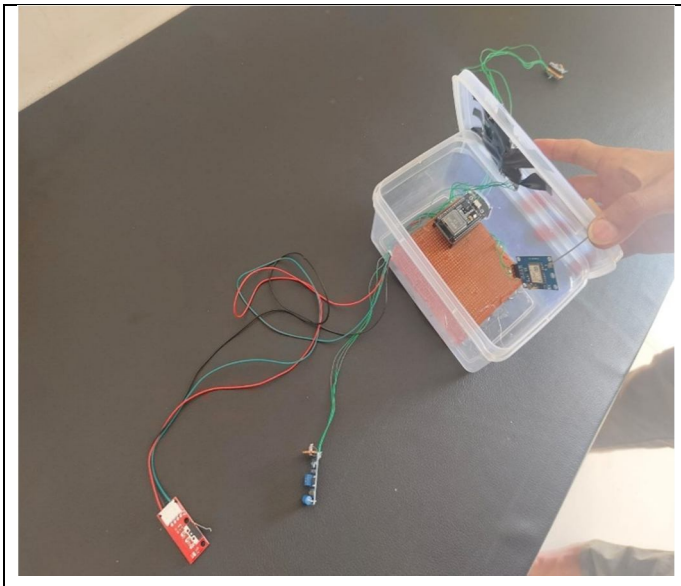
The ESP32 uses Wi-Fi connectivity to transmit data to Firebase Realtime Database. The data is categorized into:

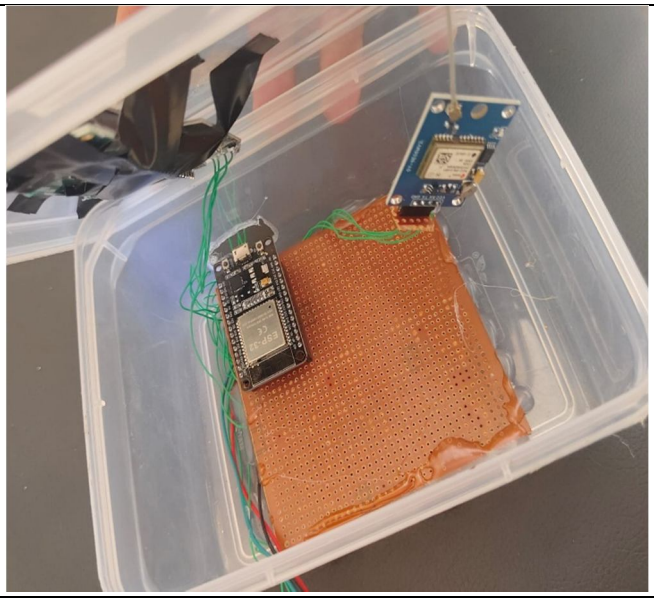
1) Live Data
- Location
- Speed
- Acceleration
- Sensor status

2) Accident Logs
- Accident location
- Speed at impact
- Timestamp

This structure enables real-time monitoring as well as historical data analysis.

VII. ALERT SYSTEM





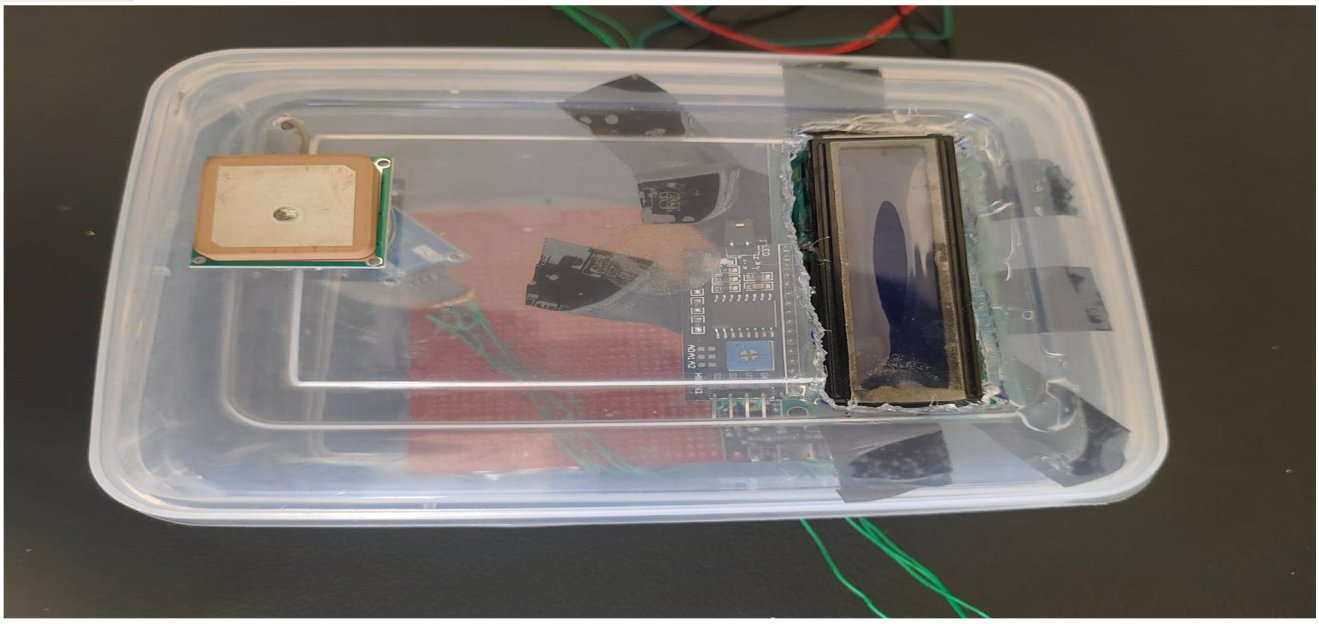


Figure 1. Hardware Prototype of Accident Detection and Vehicle Black Box System

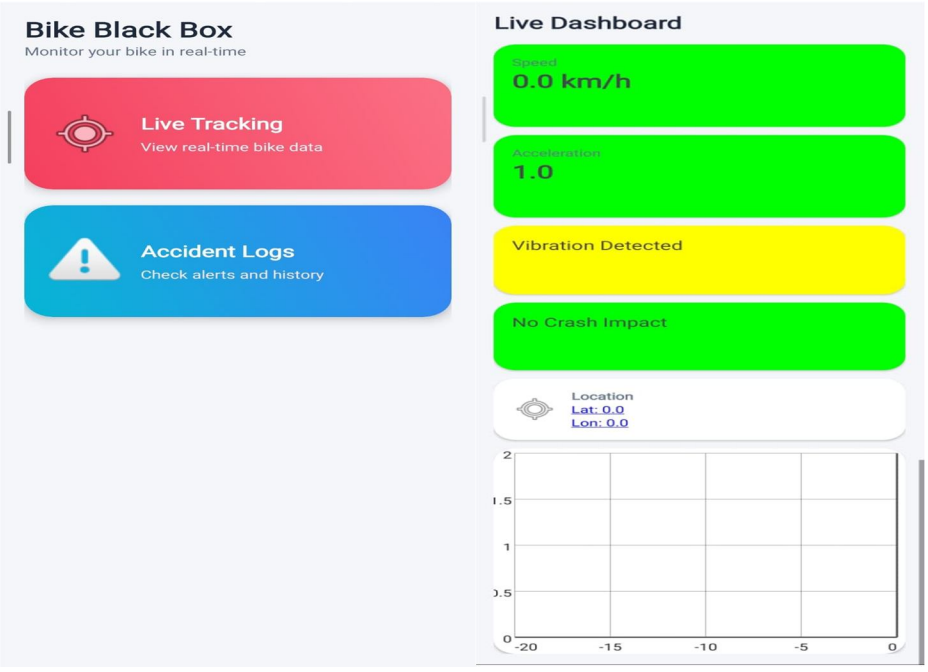
When an accident is detected, the system sends an SMS alert using Fast2sms API. The alert message contains:

- Accident warning
- Speed information
- Google Maps Link for location

This allows emergency contacts to quickly reach the accident location

VIII. RESULTS AND DISCUSSION

The system was tested under different conditions including normal riding, sudden braking, and simulated accidents. The multi-sensor approach successfully reduced false alarms and accurately detected real accident scenarios. The real-time data transmission to Firebase was consistent and reliable. The SMS alert system successfully delivered messages within seconds, ensuring quick notification.



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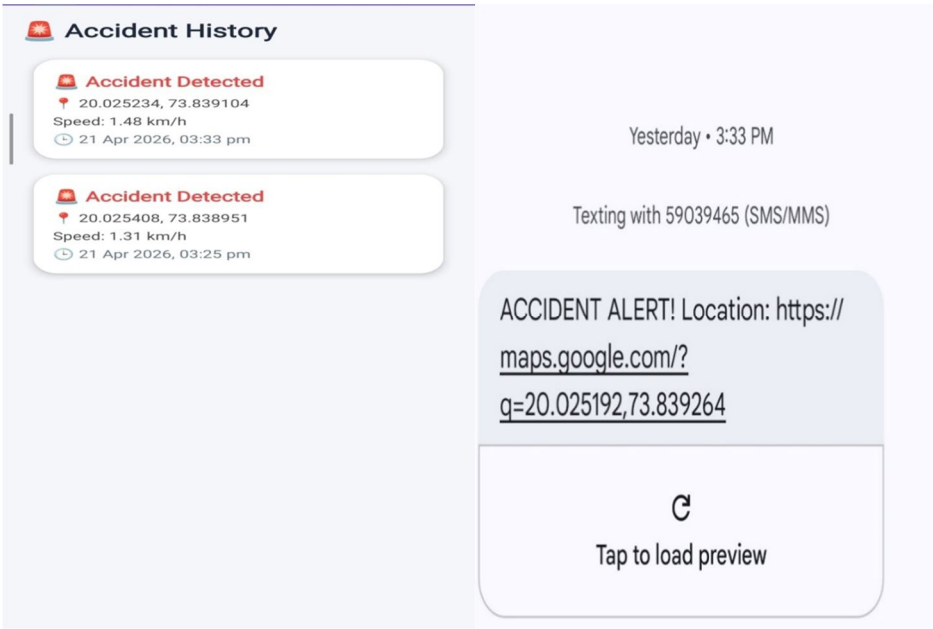


Figure 2. Results Showing Accident Detection and SMS Alert Notification

IX. ADVANTAGES

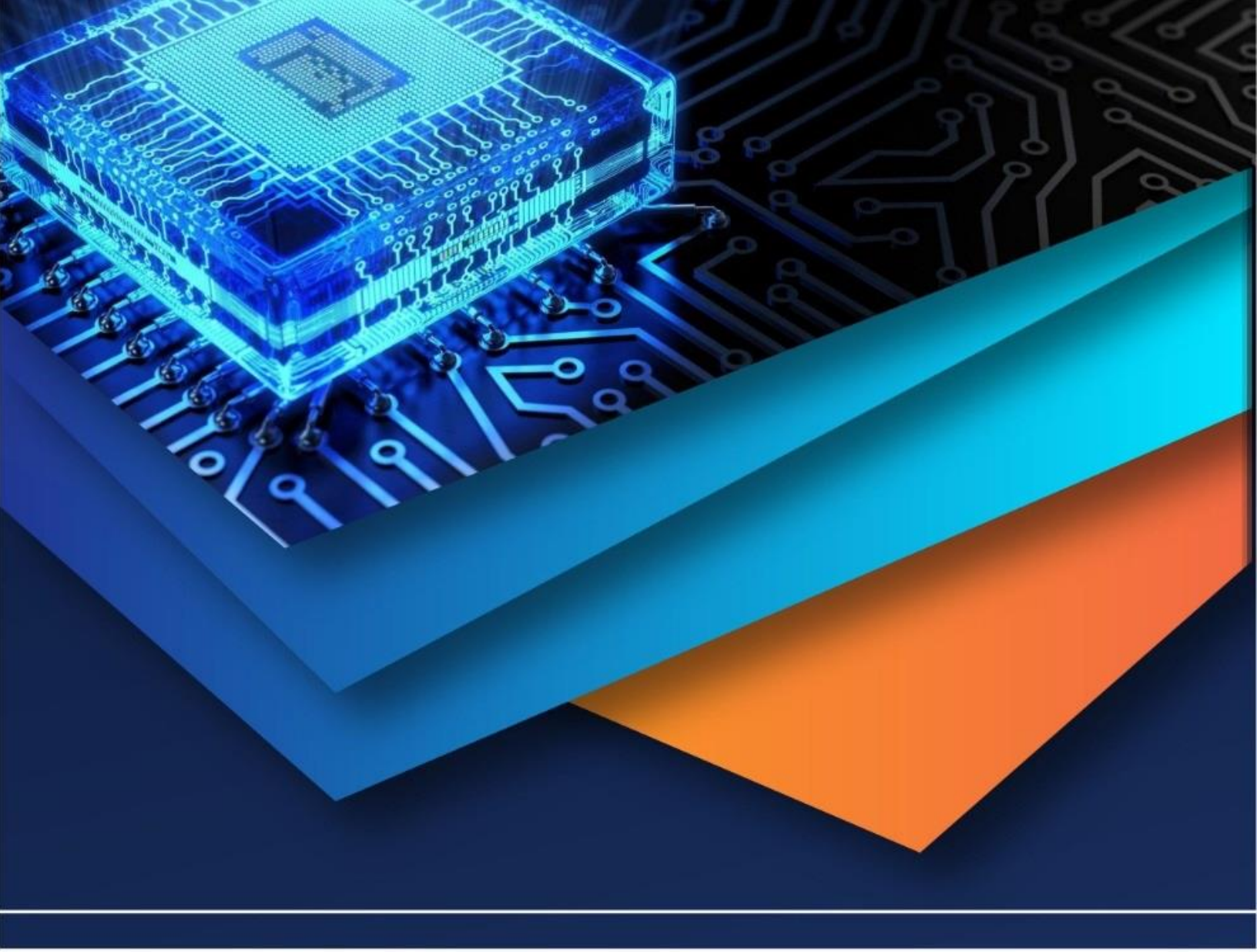
1) Real-time monitoring
2) Accurate accident detection
3) Quick emergency response
4) Low-cost implementation

X. APPLICATIONS

1) Two-wheeler safety systems
2) Fleet tracking and monitoring
3) Emergency response systems
4) Smart transportation

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