IOT-Enabled Black Box System for Two Wheelers with Real-Time Accident Detection and Emergency Alerting

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Abstract — The aim of this this paper is to introduce Black Box System for Two-Wheeled Vehicles that seeks to maximize road safety by identifying crash mechanisms, providing real time alerts, and storing important information that can be used for post- accident analysis. The system is built using minimum circuitry which makes it very inexpensive and easy to use. It tracks and records the movement of the vehicle at regular intervals. It also has cameras that take images during the accident. When a crash occurs, it sends an alert and makes an emergency call with the coordinates of the crash. Helps. Reading and photographs from the crash are saved on the SD card for further investigation. Moreover, alcohol detection functionality prevents vehicle operation under the condition of alcohol intoxication. Accident detection, GPS, and emergency image capture were all reliably verified during prototype testing. There is great potential for adding cloud storage in the future and using remote monitoring, machine learning for accidents prediction and prevention.

Keywords — Black Box System, Accident Detection, Real-Time Alert, GPS Tracking, Two-Wheeler safety, Road safety

I. INTRODUCTION

According to World Health Organization (WHO) [1], collisions on two-wheeled vehicles have continued to become a major contributing factor to road facilities. This is especially true in developing countries; however, much of the blame lies on the lack of advanced technologies in holistic safety on motorcycles & scooters. Comparison with cars reveals that two-wheelers do not have integrated medical emergency response systems, crash detection, & other technologies which complicate accident investigation processes & delays medical assistance. Moreover, transcending motorcycle hit- and-run cases is made complex by the lack of onboard accident data recorders.

To Overcome these issues, black box systems have become commonplace in cars contemporarily, especially for capturing and documenting vehicular accidents, insurance claiming's & forensic examination. Despite the fact that such technology is not prevalent in two wheelers, this research seeks to implement the idea of a Black Box System for Two Wheelers, which would capture accidents in real time, notify concerned parties, and log pivotal information during and after the accident.

The system consists of a low cost-microcontroller dubbed ESP32-CAM, which has wireless communication and image capturing capabilities. It also includes accelerometers, impact detectors, GPS modules and other sensors used for tracking vehicle movement and monitoring crashes to log important data. The system is designed to autonomously send an SMS alert with GPS coordinate which allows to set emergency contacts so that they can respond without any delays. Additionally, sensor readings and photographs are kept on an SD Card for further analysis following the accident to help with insurance & accident investigations. Also, the system comprises alcohol detection censorship with automatic ignition control that disables the vehicle if the user is detected to be intoxicated, therefore minimizing alcohol related crashes.

II. LITERATURE REVIEW

In recent years, accident detection and black box technology for two wheelers have been topics of interest. Various researches have been conducted emphasizing the improvement of response times during accidents and the analysis of post-accident events.

Fauzan et al. [2] proposed an accident detection system with the use of an ESP32-CAM module which can take pictures and send them to a remote server over

Wi-Fi. This enabled better documentation of accidents and more effective emergency responses.

Iqbal and Kousar [3] built a GPS and GSM integrated black box system that detects accidents and sends automated emergency messages including the location of the accident. Their study further corroborated the significance of microcontroller based real time accident monitoring.

Meena and Iyer [4] presented a microcontroller-based framework for automatic crash detection and notification of services for help specifically designed for two-wheeler riders. Their travaux showed better response and safety in emergency situations.

Gap Analysis:

Even with the improvements brought about by new approaches, the accident detection systems still show some shortcomings:

Neglect of two-wheeler users: Most black box applications are designed to work with four-wheeled vehicles, hence two- wheeled motorcycles are not well catered for.

Limited real time capture and image storage: The images and data pertaining to the accidents are generally not captured and stored in the cloud when the incident occurs, thus post- crash analysis becomes very difficult.

Lack of integrated safety mechanisms: Alcohol detection and ignition control mechanisms are still underexplored in two-wheeler safety research.

III. METHODOLOGY/EXPERIMENTAL

A. Components Required:

1. ESP32-CAM: Microcontroller with inbuilt Wi-Fi & Bluetooth & image-capturing capabilities.
2. MPU6050: Gyroscope & Accelerometer for impact & tilt detection.
3. NEO-6M GPS Module: Provides real-time location tracking.
4. SIM 800L GSM Module: Sends emergency SMS alerts with GPS coordinates.
5. MQ3 Alcohol Sensor: Detects alcohol presence & prevents ignition using a relay module.
6. HC-SR04 Ultrasonic Sensor: Detects frontal collisions.
7. MAX4466 Electret Microphone Module: Captures surrounding audio before and during an accident.
8. DH22 Sensor: Logs temperature and humidity at the time of an accident.
9. ESP32 inbuilt SD Card Slot: Stores sensor data and images for post-accident analysis.

B. Working Principle:

Deployment of a monitoring system for report. The system encompasses mobile sensors that gather vital data related to motion the vehicle and when an accident is detected, they photograph and record the status of all sensors. Along with the captured images, the system generates an automated alert containing the geographical location details. The system doesn't allow the engine to start in the presence of alcohol because it has an alcohol sensor built in. The GPS coordinates of the user will be sent through a SIM800L module as shown in Fig 2. Everything, before and after the accident, will be saved on the ESP32-CAM SD slot for future examination as shown in Fig 1.

C. System Architecture:

The system integrates sensors and modules with ESP32-CAM, enabling accident detection, real-time alerts & post-accident data analysis. The system follows this sequence:

1. Sensor Activation – Monitors motion and environmental parameters.
2. Accident Detection – Triggers emergency protocol when an impact is detected.
3. Data Logging – Stores accident data, including GPS location, sensor readings, and images.
4. Emergency Alert – Sends SMS notifications with GPS coordinates to predefined contacts.
5. Alcohol Detection and Ignition Control – Prevents vehicle operation if alcohol is detected.

Block Diagram:

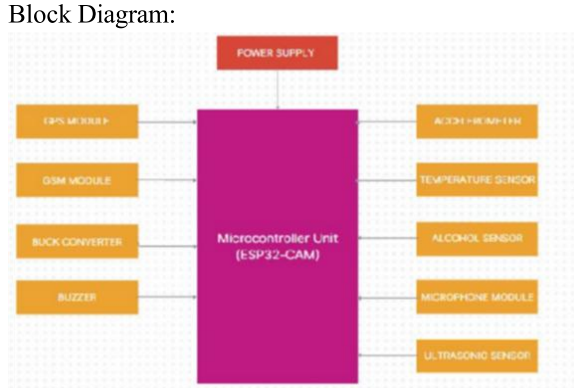

Fig 1: Black Box System

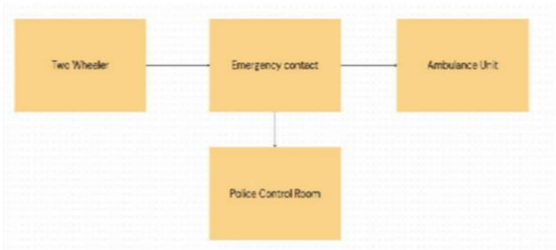

Fig 2 : SIM800L working

Algorithm:

1. Start system initialization (ESP32-CAM, sensors, GSM, GPS).
2. Continuously monitor sensor data (MPU6050, HC- SR04, DHT22, MQ3, MAX4466).
3. If acceleration exceeds a predefined threshold, confirm impact using additional sensors (HC-SR04).
4. If accident is confirmed:
   - Capture images using ESP32-CAM.
   - Record surrounding audio using MAX4466.
   - Log sensor data (MPU6050, DHT22, GPS location) to ESP32-CAM's inbuilt SD card.
   - Send emergency SMS with GPS coordinates via SIM800L.
5. If alcohol is detected, disable ignition using the relay module.
6. Continue monitoring or reset system after a predefined delay.
7. End

Schematic Diagram:

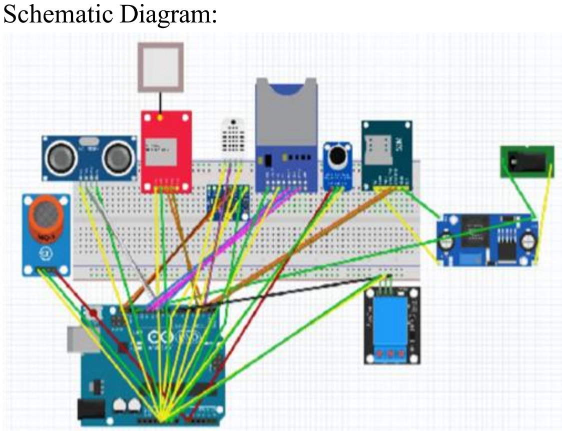

Fig 3: Prototype tested using Arduino UNO

While the schematic diagram (Fig 3) represents the system using Arduino Uno, the final implementation utilizes ESP32 for enhanced connectivity and processing.

Difference:

ESP-32 CAM has inbuilt Wi-Fi & Bluetooth feature while Arduino UNO doesn't have.

ESP-32 has 32-bit processing power while Arduino UNO has 8-bit.

ESP-32 has 36 GPIOs while Arduino UNO has 14digital & 6analog I/O Pins.

We have provided a flowchart (Fig 4) which defines full process and working of the Black Box System.

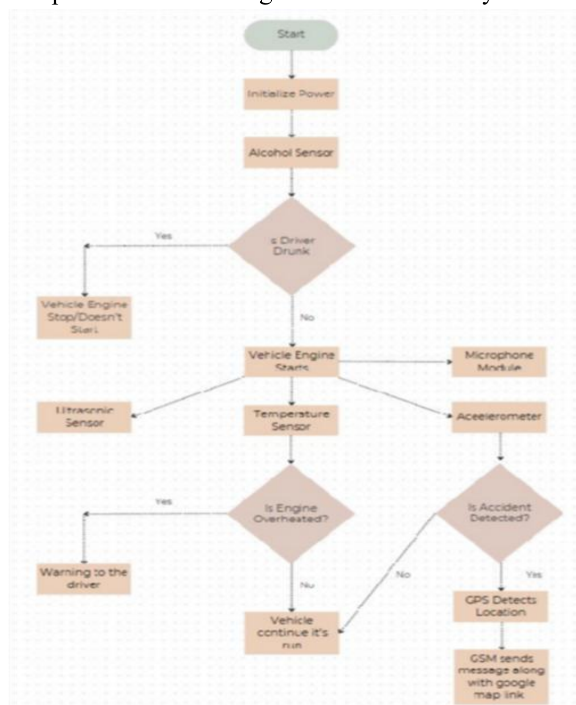

Fig 4: Flowchart defining the process

IV. RESULTS AND DISCUSSIONS

The structure of the black box system was developed and tested under varying scenarios. The impact detection system worked effectively as it detected impacts and sent SOS alerts. The GPS module provided accurate locations, and the ESP32- cam module took pictures on a scheduled basis and at the time of the incident. The ignition interlock device successfully detected alcohol and ensured that the engine would not start when driving conditions were deemed unsafe. Testing in the field proved that the device can significantly enhance the effectiveness of the response to accidents and collect data crucial for identification of the accident's circumstances.

V. FUTURE SCOPE

The black box system has the following potential enhancements:

Cloud Hosting of The Accident Data – Archiving the incident data on a cloud server for easy retrieval.

Using Machine Learning for Accident Prediction – Training operating models to reduce risks of accident occurrence.

Collaboration With Other Services – Informing police or ambulance service directly.

Advanced Energy Saving Features – Introducing sleep modes for prolonged battery life.

VI. CONCLUSION

This study delineates an efficient and effective black box system for two-wheelers that is economically feasible. It is capable of detecting accidents, giving alerts in real time as well as post accident data logging. The system effectively enhances the safety of two-wheelers in the region where it is deployed. By the use of ESP32-CAM, GPS, GSM & several sensors, the system improves the response to the accident and it's forensic evaluation. The scalability of these systems supports the improvement of road safety by providing integrated measures. As such, improvement is focused on cloud integration for data storage & AI based accident prevention in future research.

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