Black Box for LMV's and 2-Wheelers

A PROJECT REPORT

Submitted by

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ABSTRACT

This project centers on developing an advanced Black Box system specifically for domestic vehicles, taking inspiration from Event Data Recorders (EDRs) now mandatory in many Western vehicles. While EDRs capture basic information about events like crashes, this system aims to go further by gathering more detailed and insightful data. Designed to provide a comprehensive view of incidents, this Black Box will track various metrics, including GPS location, acceleration, impact forces, vibrations, and both internal and external temperatures. Additionally, it will monitor driver drowsiness and include inertial tracking data via gyroscopes and accelerometers. Engine-related parameters, such as throttle position, brake application, and fuel injection levels, will also be recorded, mostly sourced from the car's electronic control unit (ECU).

Beyond just capturing data, this system will store information in real time and continuously monitor each sensor, identifying and logging abnormal events like crashes, drifts, skids, and irregular braking. The data collected can reveal insights into the causes and handling of accidents, assessing the severity and potentially providing information useful for investigations and insurance assessments. With its expanded capabilities, this Black Box system goes beyond conventional EDRs, offering a more detailed record of events and promising enhanced safety and accountability for domestic vehicle owners.

OBJECTIVE

The primary objective of this project is to develop an advanced Black Box system specifically designed for domestic vehicles in India, including two-wheelers and light motor vehicles (LMVs). This system aims to go beyond the basic functionalities of conventional Event Data Recorders (EDRs) by incorporating a wider range of monitored parameters and analytical capabilities. The expanded objectives are as follows:

1. **Comprehensive Data Collection**:
   - Develop a system capable of capturing a variety of vehicle and environmental data, such as GPS coordinates, speed, acceleration, impact forces, temperature (internal and external), and vibration levels.
   - Include camera feeds and drowsiness detection modules to monitor driver behaviour and assess levels of alertness, which is particularly crucial for preventing accidents related to fatigue.
   - Utilize data inputs from the vehicle's Electronic Control Unit (ECU) to monitor parameters like engine throttle, brake status, fuel injection rates, and other performance metrics for a complete overview of vehicle conditions.
2. **Enhanced Accident Analysis**:
   - Enable more detailed accident reconstructions by collecting and storing critical data points both during and leading up to an incident.
   - Support the identification of root causes of accidents through data that captures not just the moment of impact but also pre-incident events, such as sudden braking, swerving, or loss of vehicle control.
   - Provide a tool that law enforcement and accident investigators can use for accurate and unbiased reports on incidents, thus aiding in liability determination.
3. **Improved Road Safety**:
   - Offer insights that help identify and mitigate risky driving behaviours, such as harsh braking, rapid acceleration, and speeding.

    - Provide real-time drowsiness detection using camera-based tracking of the driver’s eye movement and facial expressions. This feature will alert the driver when signs of fatigue are detected, potentially preventing accidents caused by driver drowsiness.
    - Use data to promote safer driving habits through feedback systems that educate drivers on their performance and encourage adherence to traffic rules.

4. **Insurance Claims and Fraud Prevention**:
    - Facilitate insurance companies' verification processes for claims by providing reliable data on accidents. This can help reduce the frequency of fraudulent claims, leading to a fairer claims settlement process.
    - Enable insurance firms to develop dynamic pricing models based on driver behaviour and vehicle usage patterns, rewarding safe driving practices with reduced premiums.

5. **Fleet Management and Logistics**:
    - Integrate real-time tracking and event monitoring for fleet operators, allowing them to manage logistics more efficiently and ensure driver safety.
    - Monitor vehicle performance and maintenance needs to prevent breakdowns and prolong the operational life of fleet vehicles.
    - Support compliance with safety regulations and improve operational transparency within fleet management systems.

6. **Data for Policy and Infrastructure Planning**:
    - Provide policymakers with valuable data that can be used to identify accident-prone areas and make data-driven decisions regarding traffic management and road infrastructure improvements.
    - Support urban planners in designing safer roads by analysing patterns in accidents and near-misses captured by the system.

- Enable collaboration with academic institutions and research bodies to study road safety trends and the effectiveness of implemented safety measures.

7. **Technological Advancement and Scalability**:
   - Create a scalable system that can be adapted for use across different types of vehicles, including motorcycles, cars, and commercial vehicles.
   - Ensure the system can be upgraded over time to incorporate new technologies such as artificial intelligence (AI) and machine learning for predictive analysis and smarter response mechanisms.
   - **Robust Testing and Simulation Environments**: Develop simulation tools that allow for testing system performance across different vehicle types. This ensures reliability and effectiveness as the system scales and adapts to varied vehicular contexts.

8. **Privacy and Data Security**:
   - Address the critical aspect of data privacy by embedding encryption and secure transmission protocols within the system. This will ensure that sensitive information is protected from unauthorized access or cyber threats.
   - Adhere to global best practices for data management, allowing only authorized users access to specific data for post-event analysis.
   - **Data Lifecycle Management**: Establish protocols for secure data lifecycle management, including data storage, archiving, and deletion policies, to ensure that sensitive information is only retained as long as necessary.

CHAPTER 1

INTRODUCTION

As of today, India is among those countries who are witnesses to a crisis of road safety as a wide range of estimates suggest that India has one of the highest rates of fatal traffic accidents in the world. People drive badly, there are traffic rules violations among the public and indifference towards the issued tickets for such behaviours – all these contribute to the distressing statistics. There is greater need of better accident investigation since it will not only address the issue of finding out reasons of road accidents, rather it'll be aimed at avoiding the confrontations altogether in the first place. EDRs have also been gradually made mandatory in automotive vehicles in the Western market with the aim to assist investigators when analysing crash incidents, due to the way vehicle faults can be disclosed from the BCEU data. But mostly they are too limited only to certain parameters such as the speed of the vehicle, brake position, and other similar variables that were monitored at the time of the crash. In this paper, we suggest the construction of a new Black Box system for the Indian market which does not only focus on basic EDR functions, but extends to incorporate capturing GPS, internal and external temperature, vibration and Camera feed with drowsiness detection capability. The system to be developed, which is meant for different categories of putting will be very helpful in the courts of law. Here are some applications of the advanced Black Box system:

1. Accident Investigation: Provides detailed data on crashes, including vehicle speed, impact forces, and driver behaviour, enabling accurate accident reconstruction and determination of liability.

2. Insurance Claims and Fraud Prevention: Helps insurance companies verify the circumstances of accidents, reducing fraudulent claims and offering lower premiums to safe drivers.

3. Driver Behaviour Monitoring: Tracks driving patterns such as harsh braking, sudden acceleration, and drowsiness, allowing for behaviour improvement and enhanced road safety.

4. Fleet Management: Enables real-time tracking and event monitoring for logistics companies, improving operational efficiency and vehicle safety.

5. Traffic Law Enforcement: Assists law enforcement in accident investigations by providing reliable data on vehicle and driver actions leading up to an incident.

6. Road Safety Improvements: Contributes to traffic safety research by offering detailed information on accident-prone areas, helping to develop better traffic management strategies.

7. Drowsiness Detection: Monitors driver alertness through camera-based tracking of eye movement, helping prevent accidents caused by fatigue.

8. Vehicle Performance Analytics: Provides insights into vehicle health and performance through data collected from the ECU, allowing for preventive maintenance and repairs.

The introduction of a Black Box system with expanded capabilities is especially relevant in India, where the high rate of road accidents has significant socio-economic impacts. Beyond individual safety, the data collected by these devices can inform policymakers and urban planners, enabling better traffic management and infrastructure development. Additionally, insurance companies can leverage this data to reduce fraudulent claims and reward safer drivers, creating a more balanced and fair assessment system. Despite the promising benefits, implementing such a system in India comes with challenges, particularly concerning data privacy and cybersecurity. Ensuring that sensitive data is protected from unauthorized access is critical to building trust among users. This project will incorporate robust encryption measures and adhere to privacy-focused data management practices to address these concerns. Overall, the deployment of a sophisticated Black Box system represents a crucial step toward modernizing road safety in India. By providing real-time data collection and analysis, this technology could pave the way for reduced road fatalities, improved driver behaviour, and a more informed approach to road safety regulations.

CHAPTER 2

LITERATURE SURVEY

1. **Design and Implementation of Event Data Recorder with Safety Parameters**

Published in: 2023 2nd International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation (ICAECA), Coimbatore, India

Authors: B. Gopinath, V. S. Yugesh, and T. Sobeka

This paper focuses on designing an EDR that records vital safety parameters, including speed, brake status, and crash impact data, which are critical for post-accident investigations. The authors propose a system that also monitors the vehicle's condition prior to the crash, allowing for a more comprehensive understanding of the accident dynamics [1].

2. **Prototype design of EDR (Event Data Recorder) on motorcycle**

Published in: 2016 International Electronics Symposium (IES), Denpasar, Indonesia

Authors: H. Alasiry, E. S. Ningrum, E. B. Utomo, and L. N. B. Nugroho

This study developed an innovative EDR prototype specifically for motorcycles, utilizing GPS and IMU sensors to track the vehicle's behavior. Unlike traditional systems that focus on cars, this prototype addresses the specific needs of two-wheelers, offering real-time monitoring of speed, orientation, and accident severity [2].

3. **Low Cost Black Box for Cars**

Published in: 2013 Texas Instruments India Educators' Conference, Bangalore, India

Authors: C. Patil, Y. Marathe, K. Amoghimath, and S. S. David

Patil et al. presented a low-cost black box solution designed for cars, targeting affordability without sacrificing essential features. The system records critical data like acceleration, speed, and location, which are vital for accident analysis. The authors emphasize the potential for widespread adoption in developing countries due to the system's cost-effectiveness [3].

4. **Real-Time Vehicle Tracking Using Integrated GPS-IMU Systems**

Published in: Journal of Transportation Technology, 2022

Authors: L. Zhang and X. Chen

This paper introduces an integrated GPS-IMU system designed for real-time vehicle tracking. The system provides accurate location data, speed history, and vehicle trajectory, allowing for precise accident reconstruction. The authors also highlight the importance of integrating these systems with existing EDR technology to enhance their overall functionality [4].

5. **Advanced Impact Analysis for Automotive Safety**

Published in : 2023 ,International Journal of Road Safety Research

Authors: Ranjan, K., & Gupta, P.

In this research paper , the primary factors monitored by EDR's include Vehicle Speed, Throttle Position, Brake Application, Airbag Deployment has been discussed. This is how a ready on shelf EDR operates. To improve upon this, more factors can be included.

6. **Road Accidents in India 2011**

   Published in : 2011 Transport Research Wing, New Delhi.

   Authors: Government of India, Ministry of Road Transport and Highways

   Research reports that this integration allows investigators to understand the context of the accident better, such as whether it occurred in a high-traffic area or a known accident hotspot.

7. **Automobile black box system for accident and crime analysis**

   Published in : 2021 International Journal of Scientific Research & Engineering Trends

   Authors: N. Tallapaneni, G. K. Hemanth, and K. Venkatesh

The current literature indicates a pressing need for more advanced Black Box systems that extend beyond the traditional EDR framework. Cameras can also be integrated into EDR's which can use advanced Algorithms for Drowsiness Detection. Drowsiness Detection is useful as it can flag Drowsiness in the user. Drunk Driving is one of the leading causes of Road Accidents . Vibration and Impact Sensors used to assess vehicle stability and detect abnormalities in driving behaviour.

8. **Data Security Challenges in Automotive Systems**

   Published in: Cybersecurity in Automotive Applications, 2022

   Authors: J. Smith and M. Lee

   This paper explores the growing challenge of securing the sensitive data collected by EDRs, particularly as more vehicles are connected to the internet. Smith and Lee emphasize the importance of robust encryption methods and secure transmission protocols to protect against cyberattacks, which could compromise both privacy and the integrity of accident data [6].

9. **Guidelines for Event Data Recorders**

   Published by: U.S. National Highway Traffic Safety Administration (NHTSA), 2021

   This report outlines the mandatory guidelines set by the NHTSA for installing EDRs in new vehicles. It specifies the parameters to be recorded, such as speed, brake application, and airbag deployment, ensuring that standardized data is available for accident reconstruction. The guidelines also stress the need for interoperability between EDR systems across different vehicle manufacturers [7].

10. **AI and Machine Learning in Road Safety**

    Published in:Journal of Intelligent Transport Systems, 2023

    Author: R.A.White

White's paper explores how AI and machine learning algorithms can be applied to analyze the vast amounts of data generated by EDRs. These technologies can predict accident hotspots and even assess the likelihood of future accidents based on driving patterns, offering a proactive approach to road safety. The integration of AI could also help optimize insurance claims and accident investigations [8].

11. **Development of Event Data Recorder for Pedestrians for Analysis of Traffic Accidents**

    Published by: Kyushu Institute of Technology, Japan, 2022

    Authors: H. Arakawa, S. Enokida, T. Hayashi, M. Ishikawa, and E. Nobuyama
    This paper introduces an EDR system specifically designed for analyzing accidents involving pedestrians. The system captures data such as pedestrian movement, vehicle proximity, and collision impact, providing a unique dataset for understanding traffic accidents from the perspective of pedestrian safety, an area that has been relatively underexplored [9].

12. **Driving Behaviour-Based Event Data Recorder**

    Published in: IET Intelligent Transport Systems Journal, 2014

    Authors: B.F. Wu, Y.H. Chen, and C.H. Yeh

    Wu et al. developed an EDR that focuses on recording driving behaviors, such as harsh braking and sudden acceleration, which are often indicators of dangerous driving. By analyzing these behaviors, the system provides insights into driver performance, which can be used to improve road safety and reduce accident risks [10].

13. **Implementation of Vehicle Driving State System with OBD-II, MOST Network**

    Published in: Proceedings of the 17th IEEE Asia Pacific Conference on Communications, 2022

    Authors: S. H. Baek, D. W. Jeong, Y. S. Park, H. S. Kim, M. J. Kim, and J. W. Jang
    This paper presents a vehicle driving state monitoring system that integrates data from the

OBD-II system and the MOST network. This allows for real-time tracking of the vehicle's operational status, which can be critical in detecting vehicle malfunctions or abnormal driving behavior, particularly in fleet management scenarios [11].

14. **Automotive Black Box Data Recovery Systems**

Published in: Digital Negative, TARO (The Traffic Accident Reconstruction Origin), 2006

Author: Don Gilman

Gilman discusses various techniques for recovering data from black boxes after an accident, focusing on the importance of preserving the integrity of crash data. The paper highlights the role of specialized tools and software in ensuring that data is extracted accurately, even from severely damaged vehicles [14].

15. **Motor Vehicle Event Data Recorder: All Things Considered**

Published in: IEEE Intelligent Transportation System Conference, Washington, 2004

Author: T.M. Kwalick

Kwalick's paper provides a comprehensive overview of motor vehicle EDRs, discussing their evolution, current applications, and future potential. The paper also addresses the legal and ethical considerations associated with the use of EDRs, particularly in relation to privacy and data ownership [15].

CHAPTER 3

SYSTEM DESCRIPTION

HARDWARE SPECIFICATIONS

1.Raspberry PI Pico

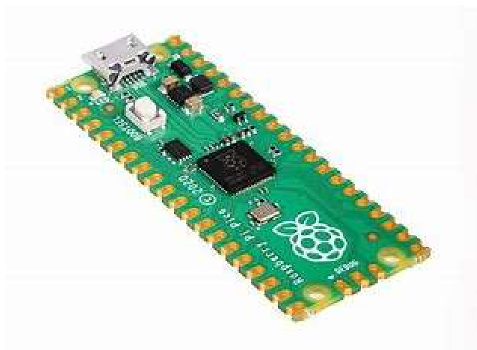

Fig3.1 Raspberry PI Pico

Description: The Raspberry Pi Pico is a microcontroller board developed by the Raspberry Pi Foundation, designed specifically for embedded applications. Unlike traditional Raspberry Pi computers, which run on Linux, the Pico operates as a lightweight, low-cost solution for controlling hardware.

Functionality: It serves as the central processing unit for the Black Box system, managing data from various sensors and executing real-time processing tasks. Its compact size and affordability make it suitable for integration into vehicles.

2.Data Storage

Fig3.2 Data Storage

Local Storage Solutions: The system utilizes onboard memory or external storage devices (such as SD cards) to log processed data continuously. This ensures that critical data is preserved even in the event of a power failure or crash.

3. Power Supply

Fig3.3 Power Supply

Power Management: The Black Box system requires a stable power supply sourced from the vehicle's electrical system. Proper power management ensures that all components function reliably during operation.

4. Camera

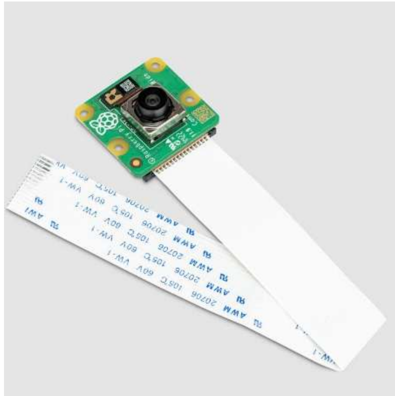

Fig3.4 Camera

Drowsiness Detection: The Black Box system also tracks drowsiness from the driver by measuring his eye-to-ear ratio. If it goes below a certain threshold, then the status is recorded and appropriate actions are taken i.e report to the local authorities or engine immobilisation. This system could resolve accidents that arise from Drink and Drive accidents.

SOFTWARE SPECIFICATIONS

Thonny IDE

Overview: Thonny is a user-friendly Integrated Development Environment (IDE) specifically designed for Python and MicroPython programming. It is particularly suited for developing applications on microcontrollers like the Raspberry Pi Pico.

Features:

- **Real-Time Debugging**: Thonny provides intuitive debugging tools that allow developers to step through code execution, making it easier to identify and fix errors.
- **Integrated Python Shell**: The IDE includes a built-in shell for testing snippets of code interactively, which is beneficial for rapid development and experimentation.

- **Automatic Error Detection**: Thonny highlights syntax errors and provides suggestions for corrections, aiding beginners in learning programming concepts.
- **MicroPython Support**: Native support for MicroPython allows developers to write code directly for embedded systems, facilitating seamless interaction with hardware components.

Programming Languages

- **Python/MicroPython**: The primary programming languages used in the Black Box system. Python is known for its simplicity and readability, while MicroPython is a lean implementation of Python designed to run on microcontrollers. This combination allows for efficient coding and control of hardware components.

Data Acquisition Scripts

Functionality: Custom Python scripts will be developed to collect data from various sensors continuously. These scripts will:

- Interface with sensors such as GPS modules, accelerometers, gyroscopes, temperature sensors, and camera modules.
- Read real-time values including speed, acceleration, temperature, and driver drowsiness.
- Utilize potentiometers to measure changes in vehicle controls (e.g., steering angle and throttle position).

Final Project

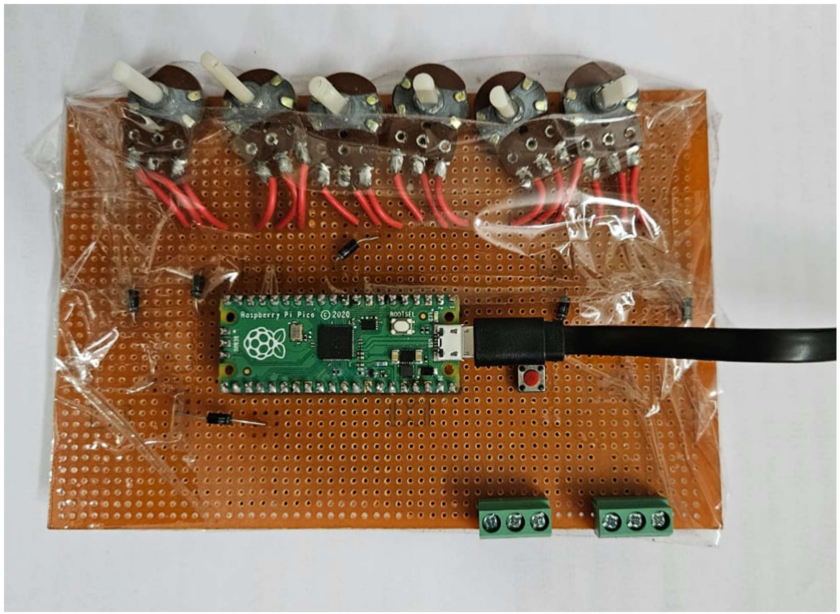

Fig3.7 Final Project

Process Flowchart:

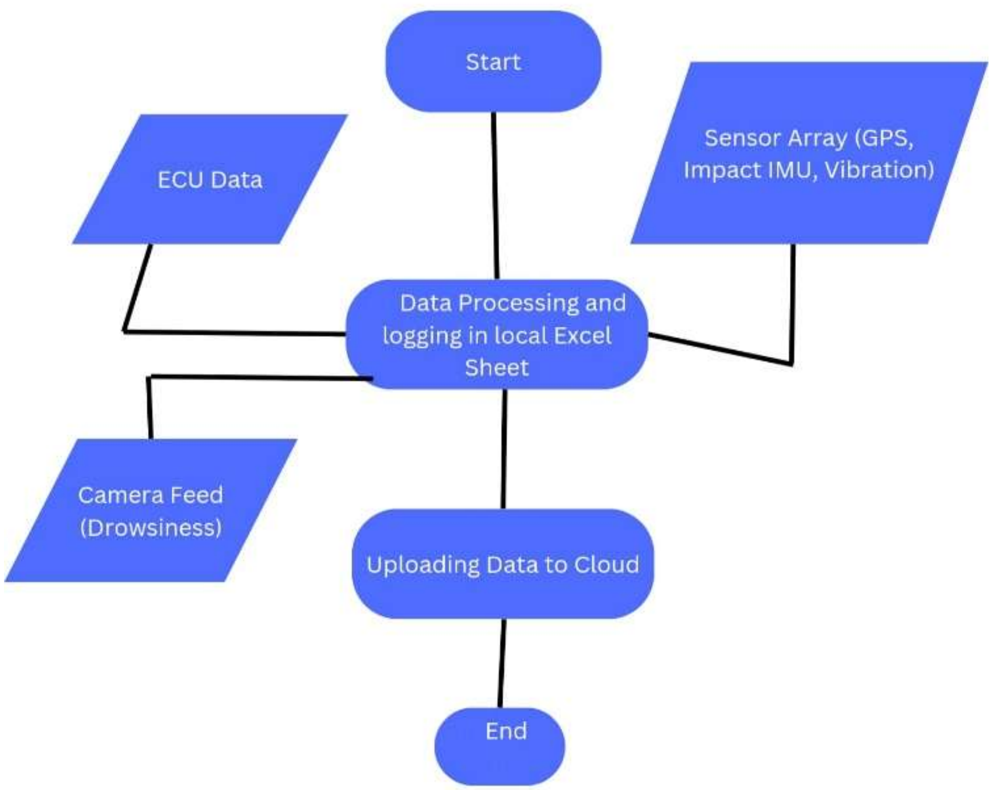

Fig 3.8 Process Flowchart

This flowchart shows how data is collected, processed, and logged before it's uploaded to the cloud. It's designed to keep track of what's happening with the vehicle and the driver to ensure safety and efficient monitoring.

1. **Start**: This is where the process begins.

2. **ECU Data**: The Engine Control Unit (ECU) gathers important information about how the vehicle is performing. This includes things like speed, how hard the brakes are being used, the position of the steering wheel, and whether airbags are active. This data is crucial for understanding how the vehicle is being driven and ensuring that all safety mechanisms are working properly.

3. **Sensor Array (GPS, IMU, Impact Sensors, Vibration):** Various sensors work together here:

- GPS tracks the vehicle's location, speed, and route.

- Inertial Measurement Unit (IMU) combines a gyroscope and an accelerometer to measure movement, tilt, and any sharp impacts.

- Impact Sensors detect sudden shocks, like those from an accident.

- Vibration Sensors monitor for unusual vibrations, which could signal mechanical issues.

4. **Camera Feed (Drowsiness Detection):** A camera focuses on the driver to monitor their alertness. This camera can use software to detect signs of fatigue, such as closed eyes or a drooping head. If the system detects drowsiness, it could prompt an alert to keep the driver safe.

5. **Data Processing and Logging in Local Excel Sheet**: After gathering data, the system organizes and saves it in an Excel sheet on a local device. This way, the data is structured and easy to review, even if there's no internet connection.

6. **Uploading Data to Cloud**: Once everything is logged locally, the data is uploaded to a cloud server. Cloud storage makes it easy to access the data from anywhere and supports further analysis, like identifying patterns over time for maintenance or safety improvements.

7**. End:** This marks the end of one cycle. The system is now ready to start collecting data again.

Overall, this flowchart describes a smooth process for collecting, saving, and sharing vehicle and driver data, creating a reliable way to monitor performance and detect potential issues.

Sensor Inputs:

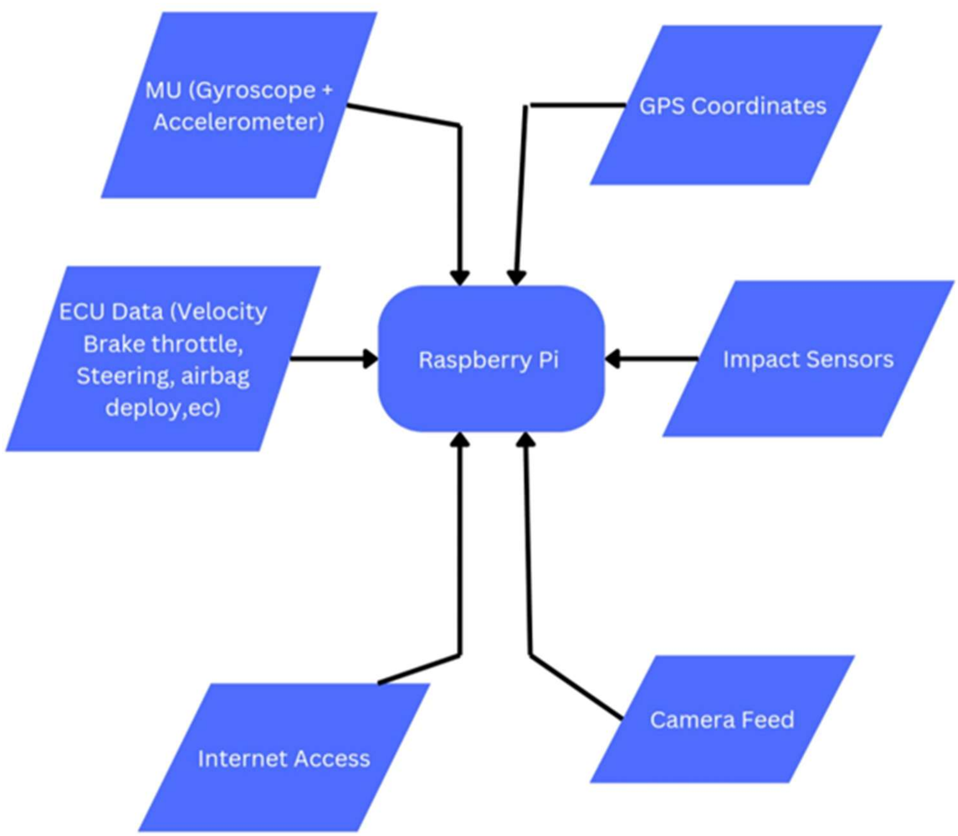

Fig 3.9 Sensor Inputs

This diagram shows how various sensors and data sources connect to a Raspberry Pi, which acts as the main data processor. Each sensor feeds specific information into the Raspberry Pi, which can then analyze the data and share it with other systems as needed.

1. **Raspberry Pi:** The Raspberry Pi is the central hub for data collection. It gathers information from different sensors, processes it, and can send it out for further analysis or storage.

2. **IMU (Gyroscope + Accelerometer)**: The IMU sensor has two parts—a gyroscope and an accelerometer. The gyroscope tracks rotation, while the accelerometer measures changes in speed or direction. Together, they help monitor how the vehicle moves, which is useful for tracking driving patterns or detecting sudden impacts.

3**. GPS Coordinates:** This module provides the vehicle's location in real time. It's useful for navigation, tracking speed, and pinpointing locations, especially in case of emergencies.

4. **Impact Sensors:** These sensors detect strong forces, like those from a collision. When the Raspberry Pi receives data from impact sensors, it can mark the event as a significant incident, which could trigger a safety response or an alert.

5**. ECU Data (Velocity, Brake Throttle, Steering, Airbag Deployment, etc.):** The ECU provides crucial vehicle performance data, including speed, throttle (acceleration control), braking pressure, steering angle, and airbag status. This gives the Raspberry Pi detailed insights into how the vehicle is behaving.

6**. Camera Feed**: A camera connected to the Raspberry Pi captures visual data. It might be used to monitor the driver's face for signs of fatigue or to capture footage of the surrounding environment.

7**. Internet Access:** By connecting to the internet, the Raspberry Pi can upload data to the cloud or send it to another server in real-time. This is useful for tracking vehicles remotely, sharing alerts, or backing up data.

This diagram shows a well-connected network of sensors all feeding data into a single Raspberry Pi, making it possible to monitor a wide range of information about the vehicle and the driver. The Raspberry Pi's role is to organize this data and, if needed, send it to cloud storage for easy access and further analysis.

CHAPTER 4

METHODOLOGY

Step-wise Methodology of the Advanced Black Box System

1. **System Design & Hardware Integration -** Sensor Integration: The first step involves interfacing various sensors with the Raspberry Pi Pico. This includes:

- GPS Module: For real-time location tracking.
- Accelerometers and Gyroscopes: To measure acceleration and orientation.
- Temperature Sensors: To monitor both internal and external temperatures.
- Potentiometers: Used for measuring physical parameters such as steering angle and throttle position.
- Camera Module: For capturing video feeds necessary for drowsiness detection.
- Wiring and Power Setup: Establish stable connections among all components, ensuring that power supply requirements are met for continuous operation.

2. Data Acquisition - Script Development: Write Python scripts to facilitate data collection from each sensor. This involves:

- Continuously reading real-time values such as speed, acceleration, temperature, and driver drowsiness.
- Utilizing potentiometers to measure changes in vehicle controls (e.g., throttle position).
- Implementing data acquisition for diodes to monitor temperature variations accurately.

3. Data Processing

Algorithm Implementation: Develop algorithms on the Raspberry Pi to process the sensor data. Key tasks include:

- Identifying abnormal driving events such as sudden braking, skidding, or impacts through pattern recognition techniques.
- Applying computer vision algorithms to analyze camera feeds for detecting signs of driver drowsiness, such as eye closure duration and head position.

4. Real-time Data Logging

Data Storage Solutions: Implement a system for logging processed data locally on the Raspberry Pi's memory or an external storage device. This includes:

- Storing critical events (e.g., collisions or rapid accelerations) with timestamps for easy retrieval during accident investigations.
- Ensuring data integrity and security during storage to protect sensitive information.

5. Event Detection

Monitoring and Alerts: The system will continuously monitor sensor inputs to detect significant events. This involves:

- Real-time analysis of data streams to trigger alerts when abnormal driving patterns are detected.

- Logging these events along with contextual data (e.g., speed, location) to provide a comprehensive overview of the circumstances leading up to an incident.

6. Data Transmission & Backup:

The Data Transmission & Backup strategy in the advanced Black Box system is designed to ensure reliable, secure, and efficient handling of critical vehicle data. By employing robust communication protocols, implementing strong security measures, and establishing reliable backup procedures, this aspect of the system plays a vital role in enhancing road safety through accurate accident analysis and driver behaviour monitoring.

- Real-Time Data Streaming: The system is designed to transmit data in real-time from the vehicle's sensors to the central processing unit (CPU) on the Raspberry Pi Pico. This includes continuous streams of information such as GPS location, acceleration metrics, temperature readings, and camera feeds.
- Periodic Backups: To enhance data security, periodic backups of the stored data can be configured to transfer copies of critical logs to a secure cloud storage solution or a remote server. This provides an additional layer of protection against data loss due to hardware failure or other unforeseen circumstances.
- Data Security Measures: Given the sensitive nature of the data collected (e.g., drowsiness detection and vehicle performance), robust encryption methods should be implemented during transmission. This ensures that any transmitted data is protected from unauthorized access or cyber threats.

7. Post-event Data Analysis:

Essential for understanding vehicle dynamics during accidents, assessing driver behavior, and supporting legal and insurance processes. By leveraging real-time data collection and advanced processing techniques, this system not only aids in accurate accident reconstruction but also contributes valuable insights that can enhance road safety initiatives and inform policy decisions.

- Evidence Collection: The detailed data collected by the Black Box serves as crucial evidence in legal proceedings related to traffic incidents. It helps establish facts about speed, braking patterns, and other critical factors that can influence liability.
- Feedback Mechanism: Insights gained from this analysis can be used to provide feedback to drivers about their driving habits, promoting safer driving practices.
- Feedback Mechanism: Insights gained from this analysis can be used to provide feedback to drivers about their driving habits, promoting safer driving practices.

8. System Testing & Calibration:

These steps ensure that the hardware and software components work together effectively, providing accurate data collection and analysis capabilities. Below is a detailed overview of the testing and calibration methodology.

1. Testing Objectives

- Functionality Verification: To ensure that all sensors, including GPS, accelerometers, gyroscopes, temperature sensors, potentiometers, and camera modules, function correctly and provide accurate readings.
- Data Integrity: To verify that the data collected is reliable and free from errors or noise.
- System Performance: To assess the overall performance of the Black Box system under various operational conditions.
- Data flow between sensors and the Raspberry Pi Pico.
- Response times of the system when multiple sensors are activated simultaneously.
- Running scripts in a controlled environment to verify they correctly read sensor data and log it as intended.
- Checking for error handling in cases where sensors may fail or provide out-of-range values.
- Algorithm Testing: The algorithms used for event detection and data processing must be rigorously tested

- Real-World Testing: Conducting field tests in real driving conditions allows for assessing how well the Black Box system performs under typical usage scenarios.
- User Interface for Calibration: Developing a user-friendly interface within the software can facilitate easy calibration adjustments by technicians or users, making it simpler to maintain accuracy.

9.Severity Levels

- Severity 0 (Fender Bender): Minor collision with no emergency action.
- Severity 1 (Moderate Accident): Medium impact; contacts emergency services if no driver response.
- Severity 2 (Severe Accident): High impact; auto-triggers emergency response, shuts off fuel and electrical systems, unlocks doors, and deploys airbags if necessary.

These sensors provide a detailed response system, activating safety measures and supporting emergency protocols in severe events.

RESULT

The following are the outputs obtained: -

```
Potentiometer Values: [187, 948, 1, 0, 0, 0, 0]
Potentiometer Values: [187, 948, 1, 170, 306, 18, 1]
Potentiometer Values: [187, 948, 1, 169, 305, 18, 1]
Potentiometer Values: [187, 948, 1, 169, 305, 18, 1]
Potentiometer Values: [187, 948, 1, 171, 307, 18, 1]
Potentiometer Values: [187, 948, 1, 170, 305, 18, 1]
Potentiometer Values: [187, 948, 1, 78, 308, 18, 1]
Potentiometer Values: [187, 948, 1, 61, 306, 18, 1]
Potentiometer Values: [187, 948, 1, 62, 305, 15, 1]
Potentiometer Values: [187, 948, 1, 62, 307, 0, 0]
Potentiometer Values: [187, 948, 1, 62, 308, 0, 0]
Potentiometer Values: [187, 948, 1, 61, 307, 16, 1]
Potentiometer Values: [187, 948, 1, 62, 307, 42, 2]
Potentiometer Values: [187, 948, 1, 61, 308, 42, 2]
Potentiometer Values: [187, 948, 1, 62, 306, 42, 2]
Potentiometer Values: [187, 948, 1, 62, 305, 42, 2]
Potentiometer Values: [187, 948, 1, 61, 307, 42, 2]
Potentiometer Values: [187, 948, 1, 62, 307, 42, 2]
```

Fig4.1 Potentiometer Values

Order of values

[Speed, brake pressure, gyroscope, engine temperature, steering, impact intensity , severity]

1. Speed (187): Current vehicle speed; helps assess motion patterns and collision severity.

2. Brake Pressure (948): Level of force applied to the brakes; indicates emergency stops or controlled braking.

3. Gyroscope (1): Detects vehicle orientation; changes may signal swerves or rollovers.

4. Engine Temperature (62): Measures engine heat; high values could indicate overheating.

5. Steering (307): Monitors steering angle, reflecting turns and evasive actions.

6. Impact Intensity (42): Collision force level; used to determine crash severity.

7. Severity (0, 1, 2): Accident impact level:

- 0: Minor (Fender Bender)
- 1: Moderate (Notify emergency if no response)

- 2: Severe (Immediate emergency response, safety actions).

25	2024-11-0	187	948	1	169	305	18	Not Drows	1
26	2024-11-0	187	948	1	171	307	18	Not Drows	1
27	2024-11-0	187	948	1	78	308	18	Not Drows	1
28	2024-11-0	187	948	1	62	305	15	Not Drows	1
29	2024-11-0	187	948	1	62	308	0	Not Drows	0
30	2024-11-0	187	948	1	62	307	42	Not Drows	2
31	2024-11-0	187	948	1	62	306	42	Not Drows	2
32	2024-11-0	187	948	1	61	307	42	Not Drows	2
33	2024-11-0	187	948	1	61	306	42	Not Drows	2
34	2024-11-0	187	948	1	61	308	42	Not Drows	2
35	2024-11-0	187	948	1	61	306	42	Not Drows	2
36	2024-11-0	187	948	1	61	306	42	Not Drows	2
37	2024-11-0	187	948	1	62	307	42	Drowsy	2
38	2024-11-0	187	948	1	62	306	42	Not Drows	2
39	2024-11-0	187	948	1	61	306	42	Not Drows	2
40	2024-11-0	187	948	1	62	309	42	Not Drows	2
41	2024-11-0	187	948	1	62	307	42	Drowsy	2
42									

Fig 4.2 Logged Data

The drowsiness detection camera monitors eye movements and blinking to identify signs of driver fatigue. If prolonged eye closure or irregular blinking is detected, it alerts the driver to stay alert, reducing accident risks.

CHAPTER 5

CONCLUSION

This project can greatly improve the safety of road users in India where thousands of people die every year on the roads. The Black Box system offered goes even beyond 5 the conventional types as it incudes real-time data gathering, drowsiness detection as well as impact sensors. Thus, such features have the ability to deliver a better understanding of accident situations, which will then back accurate analyses of incidents and promote safer driving behaviors. This data is very valuable to the insurance companies, as they can raise or lower the amount of premiums according to how the vehicle has been driven, and also for the better result coming from law enforcement in relation to investigating accidents.It could be targeted towards solving specific issues in India today; an example being frequent two-wheeler accidents and the incidence of driver fatigue.

It is applicable to wide ranges of vehicles, including two-wheelers, which makes it a scalable solution to make broader levels of implementation. Further, the data acquired could support urban planners and policymakers on building awareness towards specific accident-prone areas and improve traffic management, thus reinforcing infrastructure development and safe roads.Needless to say, this does not deal with such issues such as data privacy and system integration, but the advantages of adopting this Black Box system are very apparent in alignment with global safety standards. Definitely bound to reduce road fatality significantly and instill responsible driving habits among people in India, this technology will be deployed as a standard feature in every vehicle, paving its way for safer transportation and intelligent solutions for traffic management.

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