Automotive Black Box with Incident Analysis and Driver Sleep Detection

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***Abstract*—This project focuses on developing a safety-oriented automotive black box system designed to analyze incidents and monitor drivers. The system uses sensor data to detect the causes of accidents and monitor driver conditions, including detecting sleepiness using an ESP32-CAM. Additional features include monitoring vehicle speed to detect over-speeding, measuring temperature with a temperature sensor, and identifying alcohol consumption with an alcohol sensor. A cloud platform, connected via Firebase, provides real-time access to the collected data. This system aims to improve road safety by offering effective monitoring and instant access to critical information.**

I. Introduction

Automotive safety is a key factor in reducing road accidents and ensuring responsible driving behavior. This project integrates a smart black box system with driver monitoring to enhance vehicle safety. It uses IoT technology and sensors to detect critical issues such as overspeeding, alcohol consumption, and drowsy driving. Additionally, a temperature sensor monitors conditions, ensuring a safer driving environment. Machine learning aids in analyzing the collected data to identify emergencies and generate real-time alerts. This system not only helps in preventing accidents but also promotes accountability by recording and storing incident data on a cloud platform for further analysis.

II. Working

The system operates through a combination of hardware and software components to ensure efficient data collection, analysis, and response:

A. Data Collection and Transmission

Various sensors, including accelerometers, gyroscopes, alcohol sensors, and a temperature sensor, are connected to an Arduino board to collect real-time data about the vehicle and driver conditions.

The Arduino transmits sensor data through its TX (transmit) pin, while the ESP32 receives this data through its RX (receive) pin.

Once the data is received by the ESP32, the ESP32 uploads the data to Firebase for real-time storage and monitoring.

This seamless communication ensures that critical information, such as speed, alcohol levels, temperature, and drowsiness detection signals, is available for analysis and alerts.

B. Sleep Detection with ESP32-CAM

The ESP32-CAM is equipped with a machine learning model that analyzes video feeds to monitor the driver's alertness.

It detects signs of drowsiness, such as closed eyes for a prolonged time or a slouched posture.

If drowsiness is detected, the system sends a signal to the Arduino to activate emergency braking to prevent accidents.

C. System Flow Diagram

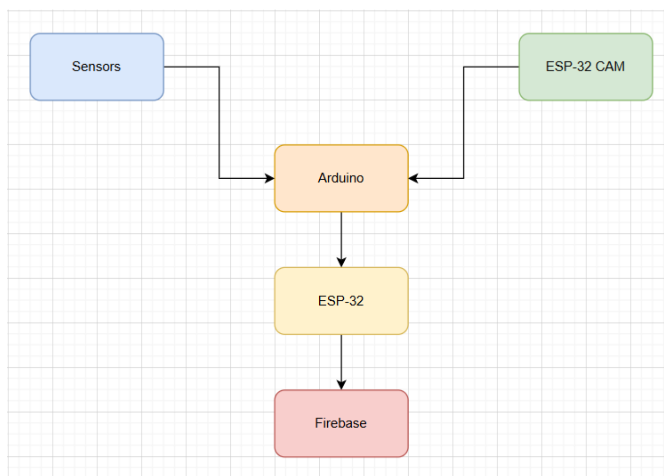

Fig. 1. System Flow Diagram

III. System Design

A. Overview

The system comprises three main components:

Arduino: Serves as the primary data collection unit. It captures real-time data from sensors, including gyroscope, accelerometer, alcohol and temperature sensors.

ESP32-CAM: Handles video analysis for detecting driver drowsiness. It uses a machine learning model to process video feeds and identify signs of sleep, such as closed eyes or a slouched posture.

Firebase: Acts as the cloud platform for data storage and access. It stores sensor and video analysis data, making it available for remote monitoring in real time.

IV. Implementation

A. Hardware

Sensors: Accelerometer, gyroscope, alcohol sensor, temperature sensor.

Micro-controllers: Arduino for data collection, ESP-32 for uploading data on firebase and ESP32-CAM for processing.

Actuators: Emergency braking mechanism triggered by critical conditions.

B. Software

Sleep Detection Algorithm: A machine learning model classifies driver states (awake vs. drowsy) using Open-CV and TensorFlow Lite, optimized for ESP32-CAM.

Data Flow: Sensor data is processed on Arduino and sent to ESP32, which uploads it to Firebase for real-time storage.

V. Testing and Results

A. Testing Scenarios

Accuracy of sleep detection: 95

Incident analysis: Reliable detection of overspeeding, alcohol levels, and critical accelerations.

B. Results

TABLE I
SYSTEM PERFORMANCE METRICS

Test Case	Success Rate	Response Time
Alcohol Detection	100%	1s
Overspeeding	100%	1s
Sleep Detection	90-95%	EspCam lag issue

VI. Future Work

Using Machine learning cloud-based analytics for comprehensive insights.

Integrating additional sensors for fatigue detection.

Developing a mobile app for real-time notifications.