Results of DUSTIN Research Activity - Smart Steering Wheel

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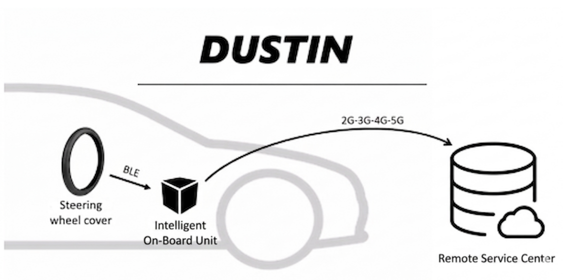

Fig. 1. Architecture of DUSTIN

***Abstract*—Driver safety is a critical pillar of Intelligent Transportation Systems (ITS), particularly in reducing accidents caused by fatigue, stress, or impairment. Traditional Driver Monitoring Systems (DMS) often rely on vision-based approaches, which can be limited by lighting conditions and privacy concerns.**

This paper presents DUSTIN (Decision sUpport SysTem for drIver moNitoring), an IoT-based DMS framework designed for the continuous, non-invasive acquisition of physiological and behavioral data. The system features a sensorized steering wheel cover equipped with a multi-modal sensor suite—including EDA, ECG, and TAC sensors—connected via BLE to an Intelligent On-Board Unit (I-OBU). The I-OBU performs real-time sensor fusion, integrating biometric signals with vehicle telemetry from GPS and MEMS sensors (accelerometer/gyroscope).

A real-time processing engine extracts key indicators to detect hazardous conditions, providing immediate feedback to the driver through an interactive voice-alert system. Data are transmitted to a Remote Service Center via MQTT over cellular networks, enabling long-term data analytics and behavioral trend assessment. The system was validated through a real-world deployment in a test vehicle, demonstrating its effectiveness in enhancing driver safety.

***Index Terms*—Driver Monitoring Systems (DMS), Intelligent Transportation Systems (ITS), Biometric Sensing, IoT, Edge Computing, Sensor Fusion, Road Safety, MQTT, Smart Cities**

I. Introduction

Road safety remains one of the most significant challenges for modern society, with human error being a contributing factor in over 90% of traffic accidents [1]. Factors such as physical fatigue, psychological stress, and alcohol impairment significantly degrade driving performance, increasing the risk of fatalities in both urban and extra-urban environments. Traditional safety measures are often reactive or rely on external law enforcement checks, which are unable to provide continuous, real-time assessment of the driver's state.

Driver Monitoring Systems (DMS) offer a data-driven alternative within the framework of Intelligent Transportation Systems (ITS). While vision-based systems (e.g., camera-based eye-tracking) are increasingly common, they are often limited by lighting conditions, privacy concerns, and the high computational cost of real-time image processing [2]. Physiological signals are highly sensitive indicators of the driver's autonomic nervous system state and can be used as early predictors of drowsiness or cognitive overload [3].

To enable large-scale deployment in the automotive market, DMS must combine non-invasive sensing, real-time edge processing, and effective human-machine interaction. This paper addresses these challenges by proposing DUSTIN (Decision sUpport SysTem for drIver moNitoring), an IoT-based architecture that integrates a sensorized steering wheel cover with an intelligent on-board unit for real-time risk assessment.

The main contributions of this work are:

- A scalable IoT-based DMS architecture for continuous and non-invasive monitoring of driver vitals;
- A real-time decision support system based on voice alerts for immediate hazard mitigation;
- Real-world validation in a test vehicle, providing a roadmap for the re-engineering and large-scale vehicular integration of the prototype.

II. Methods

A. System Architecture

DUSTIN is an integrated system designed to monitor driver biometric data and enhance road safety. The architecture consists of:

- Sensor-equipped steering wheel cover;
- Intelligent On-Board Unit (I-OBU);

- Remote Service Center;

This architecture ensures low latency, high reliability, and scalability for deployments in multiple vehicles.

B. Sensor-equipped steering wheel cover

The smart steering wheel is a battery-powered system responsible for:

- Collecting biometric data from the driver;
- Transmitting data to the I-OBU via BLE (Bluetooth Low Energy);

It is made up of the following components:

- EDA sensor: Monitors electrodermal activity (stress levels);
- ECG sensor: Monitors cardiac parameters (heart rate);
- Touch sensors: Distributed along the wheel to detect hand positioning;
- TAC (Transdermal Alcohol Concentration) sensor: Monitors alcohol concentration in the air;

C. Intelligent On-Board Unit (I-OBU)

The I-OBU acts as the central processing hub and is responsible for:

- Collecting telemetry data from the GPS and internal accelerometer/gyroscope (MEMS).
- Receive biometric data from the steering wheel.
- Real-time processing: analyzing fused data to detect dangerous situations.
- Alert Generation: provide immediate feedback to the driver via voice messages.
- Data Uplink: Sending aggregated data to the Remote Service Center.

The I-OBU software generates specific alerts based on:

- Alcohol consumption (via TAC sensor).
- Stress conditions (via EDA and ECG levels).
- Driving behavior (identifying aggressive or cautious styles via MEMS data).
- Hand position (detecting if the driver has removed their hands from the wheel).

D. Remote Service Center

The Remote Service Center enables advanced Data Analytics on historical trends to provide:

- Insights into driving styles and habitual behaviors.
- Identification of long-term behavioral changes.

III. Results

The system was deployed and tested in a real vehicle for one week. The results demonstrated the system's effectiveness in:

- Detecting hand positions on the steering wheel;
- Monitoring alcohol concentration and driver stress levels;
- Generating real-time alerts in dangerous conditions.;
- Successfully transmitting data to the Remote Service Center;

These results confirm that DUSTIN can significantly improve driver safety.

Fig. 2. Smart Steering wheel cover installed on a test vehicle

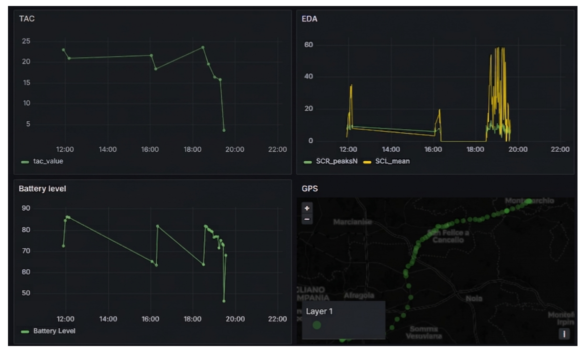

Fig. 3. Dashboard for monitoring driver status

IV. Conclusion

This paper introduces DUSTIN (Decision sUpport SysTem for drIver moNitoring), an integrated framework designed for the continuous tracking of driver biometrics. The architecture features a smart steering wheel for physiological sensing, an intelligent On-Board Unit (I-OBU) for real-time hazard detection, and a Remote Service Center dedicated to advanced data analytics.

Future work will focus on upgrading the hardware architecture of the steering wheel to improve battery autonomy and re-engineering the system for large-scale vehicular integration, while optimizing data collection methods for more complex analytics.

References

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