TRANSCOM 2025: 16th International Scientific Conference on Sustainable, Modern and Safe Transport

Advanced Driver Safety: A Steering Wheel Prototype for Real-Time Physiological and Kinematic Monitoring

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INTRODUCTION

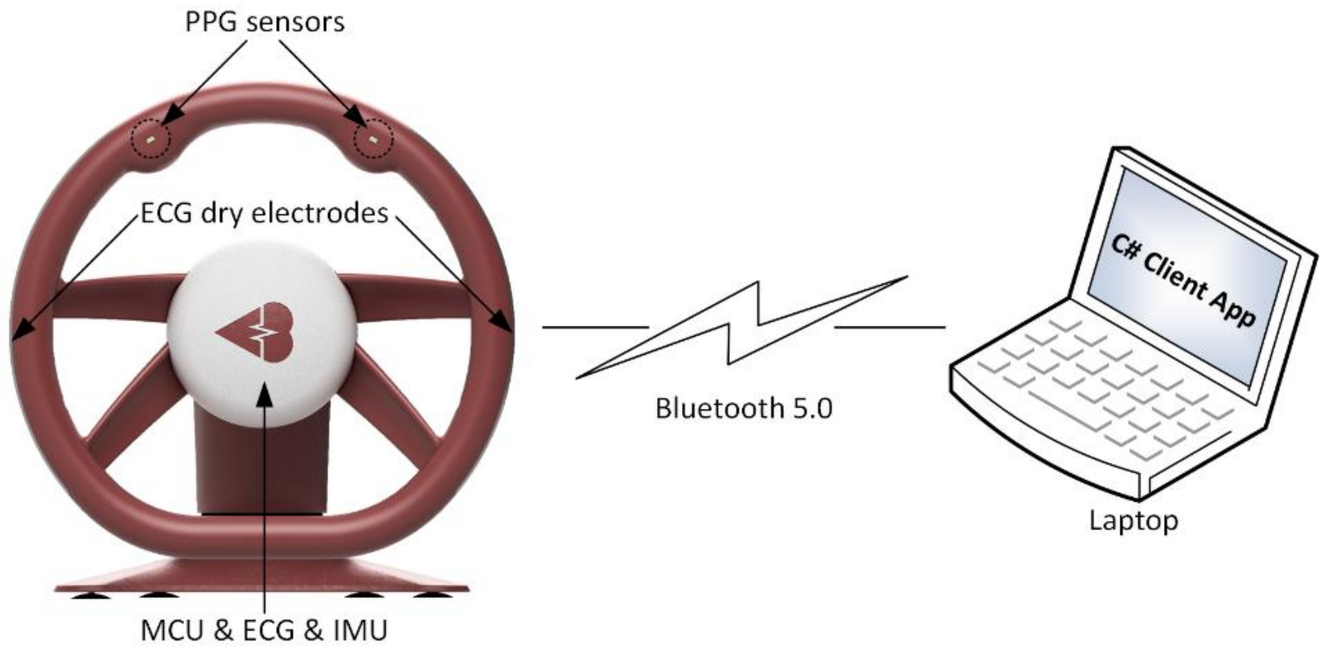
Increased transportation development has led to more traffic accidents caused by human factors, with driver fatigue contributing to approximately 20% of commercial road traffic accidents. Over half of long-distance drivers have reported falling asleep while driving.

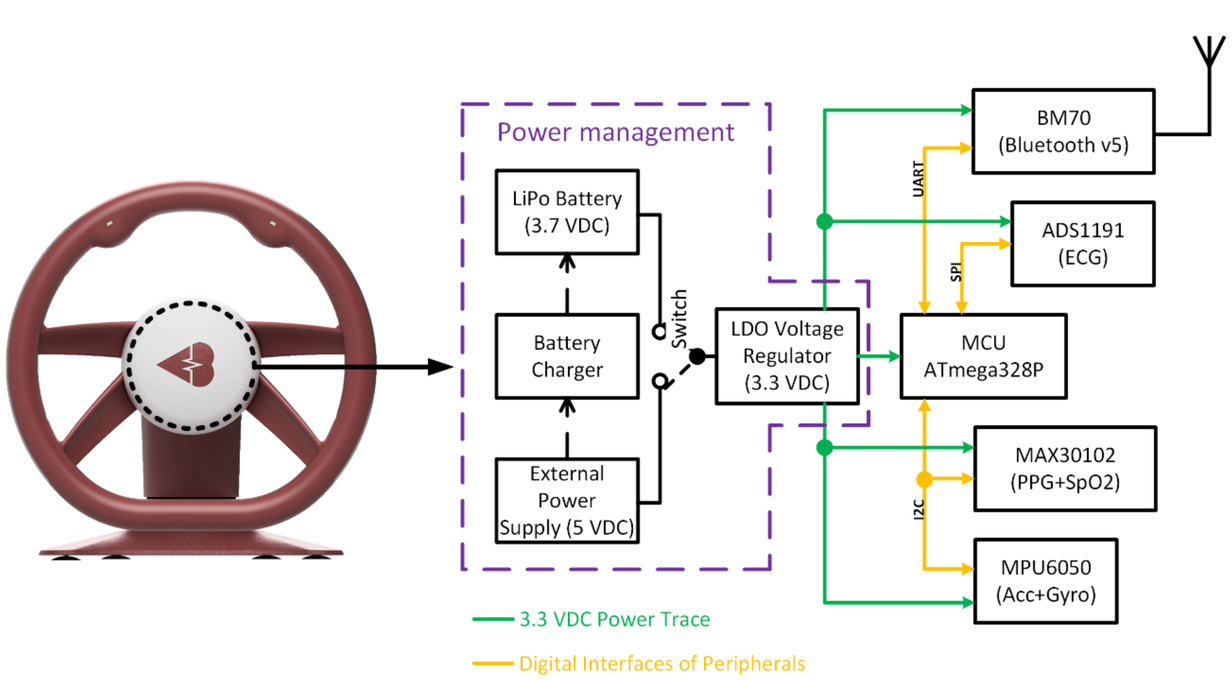
The increasing number of traffic accidents caused by human factors, particularly concentration loss and micro-sleep during long-distance and monotonous driving, highlights the need for advanced technology to enhance driver performance and safety.

The research focuses on developing a steering wheel prototype with advanced monitoring capabilities to enhance driver safety, particularly by addressing the risks associated with drowsy driving.

MATERIALS, METHODS & IMPLEMENTATION

The overall concept of the steering wheel with an incorporated sensor platform encompasses the design and fabrication of a prototype steering wheel, which will be self-supporting yet entirely operational in terms of sensory apparatus and its efficacy (the capability of pivoting left and right, vertical adjustment of the steering wheel). The sensor platform, comprising ECG, PPG, and kinematic metrics of steering wheel motion, is recorded by a data acquisition unit. Data is subsequently captured in real-time and transmitted through a wireless Bluetooth v.5 interface to a central processing unit (e.g., laptop or tablet).





RESULTS

Electronic hardware design was developed using electronic design automation software (Autodesk EAGLE v9.6.2). The hardware architecture of the steering wheel data acquisition unit, which incorporates sensors and systems for quantifying the driver's physiological and steering wheel's kinematic variables, is comprised of several principal components.

The central part of the data acquisition unit is the ATmega328P microcontroller (MCU), which processes the data received from the peripheral sensors. As an analog front-end for a single-lead ECG measurement, we used an ADS1191 circuit, interfacing with the MCU through the Serial Peripheral Interface (SPI). In order to acquire the driver's PPG signals and oxygen saturation levels, the MAX30102 sensor is employed, which communicates with the MCU via the Inter-Integrated Circuit (I2C) bus. The rotational movements of the steering wheel are detected by the inertial sensor MPU6050, which encompasses a three-axis accelerometer and a three-axis gyroscope; communication is similarly executed via the I2C protocol. The wireless transmission of the acquired data to the central unit is accomplished through the Bluetooth module BM70, interfaced using the Universal Asynchronous Receiver-Transmitter (UART) protocol.

The final prototype of the sensor steering wheel was manufactured using the additive SLS printing technology. It is equipped with a complete set of electronic components; it constitutes an autonomous device for laboratory experimental measurements during simulated vehicle driving.

CONCLUSION & IMPLEMENTATION PATH

The paper presents the design and development of an innovative steering wheel prototype with advanced monitoring capabilities. Integrating physiological sensors, including ECG and PPG, alongside kinematic metrics allows for real-time assessment of signal features, which is crucial in mitigating the risks associated with drowsy driving. This prototype could serve as a foundation for future innovations, enabling the integration of advanced technologies such as artificial intelligence and machine learning to analyze measured multi-modal data further to detect driver's health status or drowsiness risk in real-time.

ACKNOWLEDGEMENTS

This work was supported by the Slovak Research and Development Agency, grant number APVV-19-0290 and grant number APVV-22-0423.