A System for Driver Drowsiness Detection Based on ECG-Derived HRV Analysis

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***Abstract* — Driver fatigue or drowsy driving is a significant contributing factor to road fatalities. This paper focuses on the design and implementation of a system for the analysis of biosignals, intended for monitoring the vital functions of drivers and drowsiness detection. Detection system is based on monitoring alterations in autonomous nervous system (ANS) activity, which is measured non-invasively from hearth rate variability (HRV), obtained from ECG sensors implemented in steering wheel. The resulting system enables objective fatigue evaluation by comparing current parameters with the driver's individual baseline. Analysed data were measured at an experimental workstation dedicated to monitoring driver vital signs (Project APVV-22-0423). Experimental results demonstrate the functionality of the proposed solution as a support system for biomedical research in transportation.**

Keywords — driver drowsiness detection, vital functions, heart rate variability (HRV), steering wheel ECG

I. Introduction

The contemporary automotive industry is undergoing one of the most significant transformations in its history. With the advent of Intelligent Transport Systems (ITS) and the incremental deployment of higher levels of vehicle automation, the issue of safety, where the human factor continues to play a critical role, has come to the forefront. Although modern Advanced Driver Assistance Systems (ADAS) can substitute for the driver in various scenarios, the responsibility and the necessity for take-over readiness remain with the human operator in partial and conditional automation stages (SAE Levels 2 and 3). In these critical moments, the vehicle's ability to accurately evaluate the psychophysiological state of the driver becomes a fundamental prerequisite for driving safety.

One such psychophysiological indicator is Heart Rate Variability (HRV). It represents the result of the dynamic interaction between the primary branches of the Autonomic Nervous System (ANS) the sympathetic and parasympathetic (vagal) nerves which extensively innervate the heart and regulate its activity to maintain homeostasis or adapt the organism to situational demands [1]. HRV is characterized by several parameters calculated in both the time and frequency domains; for each parameter, we monitor fluctuations (increases or decreases) that could be interpreted as indicators of increased driver fatigue. The general trend during the onset of fatigue is an increase in HRV caused by a gradual decline in sympathetic activity, which is typically associated with alertness, concentration, and physical performance. Concurrently, an increase in parasympathetic activity linked to regenerative processes and, consequently, a loss of attention can be observed.

II. Materials

The data designated for visualization and analysis were acquired using a comprehensive system for monitoring vital signs. The setup utilizes a simulated environment where the participant's task is to operate a vehicle for 60 minutes to induce fatigue. To simulate monotonous driving, the game Desert Bus VR was employed, with its controls specifically modified for the purposes of this experiment. The experimental procedure involves driving on a straight road without obstacles or interruptions, which imposes a significant cognitive load on the subject to maintain attention.

This paper analyses data from a smart steering wheel used to control the vehicle during the simulation. The steering wheel is equipped with ECG sensors located on its lateral sides (a) and a PPG sensor positioned where the driver's left thumb is expected to rest (b), as shown in Fig. 1. Furthermore, the steering wheel features an integrated gyroscope to record steering rotation profiles. Button (c) is utilized to initiate a Bluetooth connection with the user interface. The sampling frequencies for the acquired biosignals are 250 Hz for ECG and 100 Hz for both PPG and gyroscopic data, with all signals recorded using the int16 data type.

The current dataset consists of 23 measurement sessions, each with a duration of approximately 60 minutes. These measurements were conducted on healthy subjects ranging in age from 20 to 54 years. To facilitate data storage, a database system was developed based on a MariaDB relational database. Storing data within this system enables efficient data access through functions implemented in the MATLAB environment.

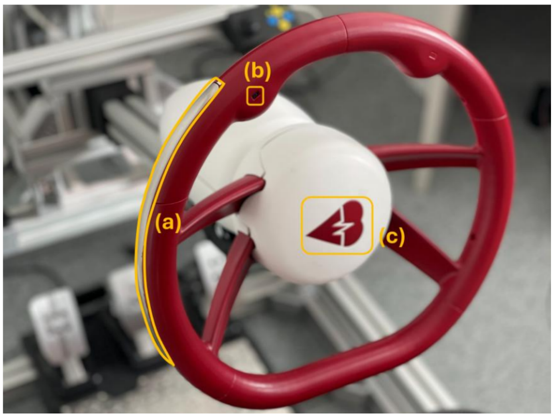

Fig. 1. Smart steering wheel with integrated ECG (a) and PPG (b) sensors and with button for bluetooth connection (c)