Driver Drowsiness Detection Using Single-Channel Dry EEG

Xiaomu Song[1], Suk-Chung Yoon[2], Eric Rex[1], Jason Nieves[2], Caleb Moretz[1]
1. Electrical Engineering Department, 2. Computer Science Department, Widener University
{xmsong,syoon}@widener.edu

An estimation from the National Highway Traffic Safety Administration indicates that an average of 83000 vehicle accidents is the direct result of driver drowsiness in each year from 2005 to 2009 [1]. Another estimation from the Massachusetts Special Commission in 2009 shows that there could be about 1.2 million and 500,000 injuries annually caused by drowsy driving, resulting in 60,000 injuries and 8,000 fatalities [2]. Typical reasons causing drowsy driving include sleep issues, risky driving patterns, the use of sedating medications or alcohol, and interactions among these factors [1].

Behavioral interaction and medical treatment are usually considered for risky driving patterns or medical issues. For a broader group of drivers, driver alert devices are a popular option. A driver alert device does not prevent a driver from being drowsy. Instead, it allows the driver to be aware of his/her condition and take the necessary precautions. Various devices have been developed to detect driver drowsiness. Some identify abnormal driving patterns by checking steering input from electric power steering system of vehicle [3]. Video cameras are also used to perform vehicle position in lane monitoring [3]. Real-time driver eye/face monitoring technique can extract eye, face, or head movement features and identify signs of drowsiness [4]. Most of these techniques rely on indirect measures that are assumed to be associated with driver drowsiness and are not always reliable. Efforts have been made to seek reliable measures based upon driver's physiological signals, such as changes of brain activity [5]. This type of techniques requires a setting of on-body sensors. Electroencephalography (EEG) has been widely used to identify changes of brain activity associated with drowsiness because signal variations in some EEG frequency bands are associated with an increased or decreased brain concentration [6]. Most existing systems reply on multi-channel EEG devices, which are expensive and need conductive gel to obtain required signal quality. The preparation of such an EEG system takes from 15 minutes up to more than one hour, which is not convenient for daily driving activities [6].

In this work, an easy-to-use and cost-efficient driver alert system is proposed. It consists of a single-channel NeuroSky dry EEG headset and an Android smartphone. The EEG headset is powered by an AAA battery and can acquire a brain signal at a sampling rate of 512Hz. It has an electrode directly placed on the forehead without using conductive gel, and its cost is significantly less than that of a multi-channel EEG. After a brief training, a user can easily put the headset in position in less than 15 seconds. A smartphone software application (APP) based upon the Android operation system was developed to implement data communication and signal processing. EEG data received by the smartphone are transformed into the frequency domain. Band power values in the alpha and beta bands are computed as features. A nonlinear Support Vector Machine (SVM) is trained to detect drowsiness using the band power features. An unlocked Android BLU R1 HD smartphone is used in the system. It has a 1.3 GHz quad-core processor, 16 GB internal memory and 2 GB RAM. An experimental study was performed to evaluate the system with a protocol approved by Widener University Institutional Review Board. Five healthy subjects participated in the study. In the experiment, multi-trial EEG data were acquired from each participant on four different days over two weeks. The experiment on each day was divided into two sessions: training and testing. In each session, the participant performed a list of tasks consisting of 100 "alert" trials and 100 "fatigue" trials. All trials were interleaved in a random order with a 5-second transition between them. The data from training session were used to train the SVM to classify the data acquired from the same participant during the testing session. The classification accuracies averaged over all four test sessions for the five individuals are 86.9%, 88.38%, 78.33%, 87.84%, and 85.37%, respectively. The accuracies of the four test sessions averaged over the five participants are 84.79%, 86.12%, 83.71%, and 86.86%, respectively. The overall accuracy averaged across all participants and sessions is 85.37%. It was observed that the accuracy varies across subjects and test sessions. This is not surprising because EEG exhibits significant within- and between-subject variations, and generally between-subject variation is greater than within-subject variation. This is the major reason that such a system is trained and used for an individual user.

REFERENCES

[1] https://www.nhtsa.gov/risky-driving/drowsy-driving

[2] "Asleep at the Wheel", Report of the Special Commission on Drowsy Driving, State of Massachusetts, 2009.

[3] Driver drowsiness detection. Robert Bosch GmbH. Nov. 2015.

[4] D Walger, T Breckon, A Gaszczak, T Popham. A comparison of features for regression-based driver head pose estimation under varying illumination conditions. Proc. IEEE Int. Workshop on Computational Intelligence for Multimedia Understanding, Nov. 2014.

[5] G Yang, Y Lin, P Bhattacharya. A driver fatigue recognition model using fusion of multiple features. IEEE Int. Conf. Syst. Man Cybern., vol. 2, pp. 1777-1784, 2005.

[6] C Lin, R Wu, S Liang, W Chao, Y Chen, and T Jung. EEG-based drowsiness estimation for safety driving using independent component analysis. IEEE Trans. on Circuits and Systems, vol. 52, no. 12, pp 2726-2738, 2005.

Widener University School of Engineering

Widener University College of Arts and Sciences

Driver Drowsiness Detection Using Single-Channel Dry EEG

Xiaomu Song[1], Suk-Chung Yoon[2], Eric Rex[1], Jason Nieves[2], Caleb Moretz[1]

1.Electrical Engineering Department, School of Engineering

2. Computer Science Department, College of Arts and Sciences

Widener University, Chester, PA 19013

I. Introduction

An estimation from the National Highway Traffic Safety Administration shows that an average of 83000 vehicle accidents is the direct result of driver drowsiness in each year from 2005 to 2009 [1]. Another estimation from the Massachusetts Special Commission in 2009 shows that there could be about 1.2 million and 500,000 injuries annually caused by drowsy driving, resulting in 60,000 injuries and 8,000 fatalities [2]. The goal of this work is to reduce driver drowsiness/fatigue induced vehicular accidents by instantaneously monitoring brain concentration using brain-computer interfacing.

II. Driver Drowsiness

- Major reason: sleep issues, risky driving patterns, use of sedating medications or alcohol, and interactions among these factors
- Solutions
  - Behavioral interaction and/or medical treatment
  - Driver alert devices

III. Proposed System

Figure 1. Block diagram of the proposed system

- A single-channel MindWave™ dry electroencephalograph (EEG) headset is used to acquire brain signals from a driver.
- The EEG data are sent to an unlocked Android smartphone in real-time.
- A smartphone software application (APP) was developed to perform
  - Data communication
  - Feature Extraction: EEG band power
  - Support vector machine (SVM) data classification: “alert” versus “fatigue”.
- An identified “fatigue” state will trigger an alarm ringtone from the smartphone.

IV. Experimental Study

- Five healthy experiment participants
- Data of each participant were acquired on four different days
  - 200 “alert” and 200 “fatigue” trials on each day
  - Duration of each trial: 2 seconds
  - Between-trial transition: 5 seconds
- A half of “alert” and “fatigue” trials were used for data classifier training, and the other half for evaluation.
- The experimental protocol was approved by Widener IRB.

V. Results

Table 1. Classification accuracy (%).

	Test 1	Test 2	Test 3	Test 4	Average
Subject 1	85.53	86.67	87.84	87.57	86.90
Subject 2	89.86	86.33	87.57	89.74	88.38
Subject 3	64.27	76.73	79.63	82.54	75.79
Subject 4	85.28	93.47	84.55	88.07	87.84
Subject 5	88.81	87.33	78.94	86.38	85.37
Average	82.75	86.12	83.71	86.86	84.86

VI. Graphic User Interface

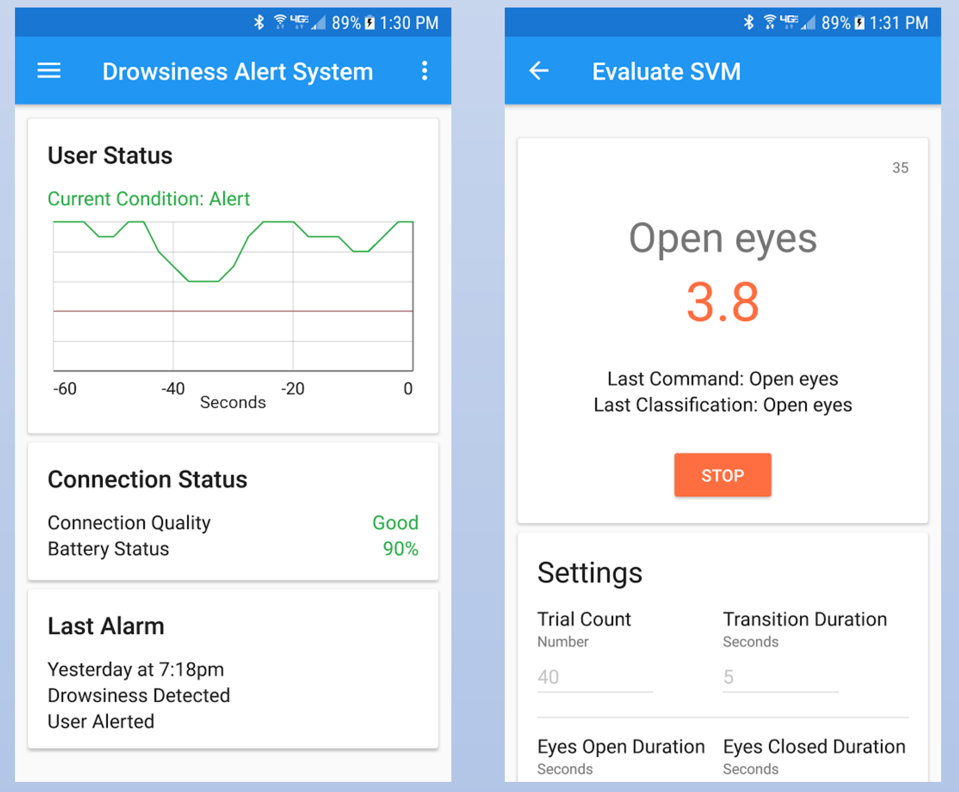

Figure 2. Left: main screen; Right: evaluation screen

VII. Conclusion

The proposed system was successfully implemented and tested using experimental data. It can acquire EEG data from a driver and provide a real-time analysis of the driver’s brain concentration level. The system was developed based on the Android system, and will be extended to iOS and other operation systems in the future.

References

[1] https://www.nhtsa.gov/risky-driving/drowsy-driving

[2] "Asleep at the Wheel", Report of the Special Commission on Drowsy Driving, State of Massachusetts, 2009.