Wearable Driver Drowsiness Detection Using Electrooculography Signal

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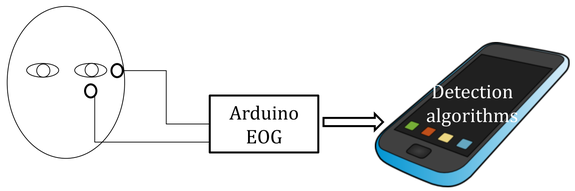
INTRODUCTION

Every year, more than 100,000 automobile crashes are caused by driver drowsiness. Various technologies have been developed to address this issue, including vehicle-based measurements, behavior change detection, and physiological signal analysis. Both vehicle-based measurements and behavior change detection identify the driver's drowsiness too late for effective accident prevention. The physiological signal changes in an early stage and can be used to detect the on-set of driver drowsiness.

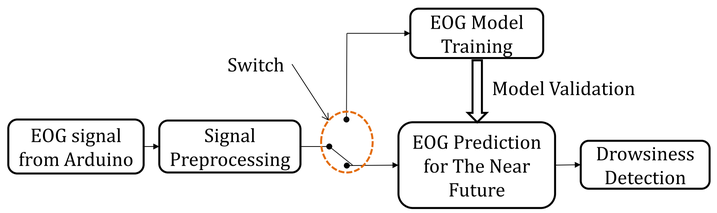
A wearable drowsiness detection system is developed using Electrooculography (EOG) Signal. The system

1. measures the EOG signal
2. transmits the signal to a smartphone wirelessly
3. alarms the driver using a drowsiness detection algorithm

The system is compact, comfortable, and cost effective. The drowsiness detection capability helps a driver to correct the behavior, and ultimately saves lives.



Schematic of a portable drowsiness detection device

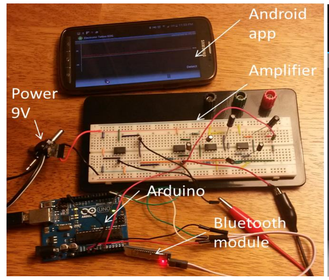


Signal processing diagram

HARDWARE DESIGN

This drowsiness detection system consists of

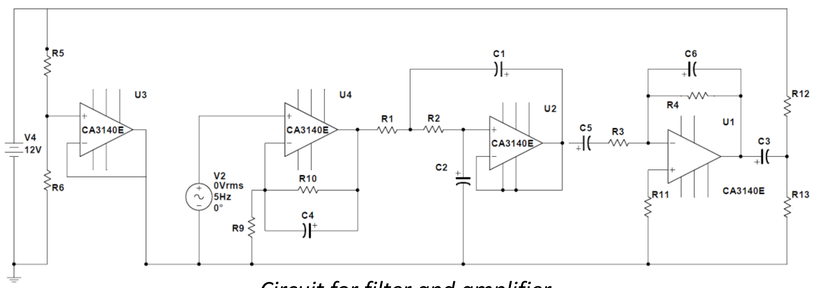
- EOG electrodes (across the temple and below the eye)
- a signal amplifier
- a data acquisition and transmission unit based on Arduino
- a smart phone app for early drowsiness detection algorithm



Drowsiness detection system

Sample EOG signal

An electronic circuit was developed to filter and amplify the signal so that it can be transmitted to an android phone through Bluetooth communication. The circuit was developed to include a virtual ground and second order Sallen-Key filters. The proof-of-concept prototype circuit was built on a breadboard.



Circuit for filter and amplifier

- Digitized signal was sent out using a HC-06 Bluetooth module that was connected to the Arduino.
- An android app was developed to read and display the EOG signal on the screen.
- An algorithm was developed to send out an alarm when the input signal surpassed a preset threshold, which indicates the driver's drowsiness.

Drowsiness Detection Algorithm

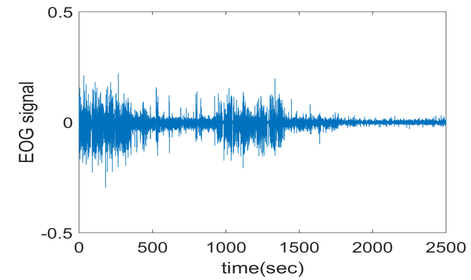
An autoregressive moving average (ARMA) model is trained using the collected EOG signals. The trained model is used for 0.5s ahead prediction of EOG voltage.

$$X_t - \phi_1 X_{t-1} - \ldots - \phi_n X_{t-n} = a_t - \theta_1 a_{t-1} - \ldots - \theta_m a_{t-m}$$

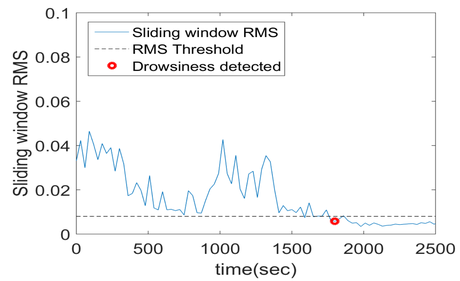
The sliding window root mean square of the predicted EoG signal for each 30 seconds is obtained as

$$\mathrm{RMS}_i = \sqrt{\frac{1}{n}\sum_{j=n(i-1)+1}^{ni} x_j^2}$$

The calculated RMS is compared with a predetermined threshold value. A warning algorithm detects drowsiness and subsequently alarms the user when the RMS is below the threshold for more than 1 minute.



Raw EOG signal



Sliding window RMS and drowsiness detection

The algorithms are implemented and embedded in a smart phone application.

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