Methodological Article

Designing a Glass Mounted Warning System to Prevent Drivers to Fall in Sleep Based on Neck Posture and Blinking Duration

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Abstract

Background: In this study, an electronic system based on driver's neck position and blinking duration is designed to help prevent car crashed due to driver drowsiness. When a driver falls in sleep his/her head is felled down. Hence, driver's neck posture can be a good sign of sleep which is measured utilizing a two?dimensional accelerator. However, this sign is not enough because he/she may need to look down during a drive and alarming driver by every moving down of head can be annoying. **Methods:** Thus, in this system, we used blinking duration too. When a person is awake, blinks more frequently than when he is drowsy. **Result:** As a result, in this system, blinking is detected using an infrared transceiver and if both conditions, i.e., neck posture and blinking duration are showing signs of sleep mode, driver will be alarmed. **Conclusion:** In this study, it is designed 2D accelerometer and IR sensor based system to measure the driver's neck angle and detect driver's blinking to realize the drowsiness of vehicle drivers and alert them using these signs of drowsiness.

Keywords: *Accelerometer, blink duration, driver drowsiness*

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Introduction

According to the *Global Status Report on Road Safety* on road safety 2018,[1] the number of annual road traffic deaths has reached 1.35 million. Drowsiness during driving and its role in car accidents causing injuries and death is reported in different studies.[2-6] A wide variety of driver drowsiness alarming systems based on either vehicle information or driver physiological information has been designed.[7-9] In reported alarming systems based on driver's physiological information, different strategies has been adopted like drowsiness detection by recording and analyzing electroencephalogram, electrocardiogram, respiration, and electrooculography (EOG) for blink detection.,[10-25] However, all of them are yet very obtrusive mainly because utilizing them needs to use sticky electrodes. Even studies in witch blink duration are measured to detect drowsiness use EOG and have no choice but using sticky electrodes.

In this study, a glass mounted warning system is designed to prevent driver to fall in sleep using driver's neck posture and blink duration. When a driver is sleepy, it is quite difficult for him to keep his head up. Therefore, driver's neck posture can be a good sign of sleepiness. This parameter can be measured utilizing a two-dimensional (2D) accelerator which is mounted on the temple of the driver's eyeglasses. This parameter might be insufficient for recognizing sleepiness in a driver due to two reasons. First, some drivers may keep their head up even when they are drowsy. Second, alarming the driver with every head falling could be annoying because at some occasions he may need to look downward while driving. Thus, to improve the accuracy of the system in detecting the drowsiness of a driver, another parameter that indicates the drowsiness should be used. In this study we use the driver's blink duration for this purpose. As mentioned above, blink detection using EOG signal is very obtrusive because in this method sticking electrode(s) on the drivers' face is required. In the present system, an infrared (IR) transceiver mounted on the glass frame above drive's eye is utilized to detect the driver's blinking. In the next section, the hardware of designed system is described in details.

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Subjects and Methods

As mentioned in the previous section, tilted head can be used as one of the signs of drowsiness of a driver. To detect the tilt of the head, a 2D-accelerometer module (MMA 7361) is used in this work. The accelerometer measures the angle between its x and y axis and gravity axis of the earth to give two voltages that are proportional to the tilt angles with respect to the horizontal plane. These analogue voltages are converted to digital signals using an analogue-to-digital converter (ADC) and then are given to a microcontroller for noise reduction and translation into tilt angles. For the proof-of-concept, an Arduino-Nano system with ATMEL Atmega328 microcontroller and embedded ADC is for this purpose.

As mentioned earlier, to increase the accuracy of the system, the duration of driver's blink is used as another sign of drowsiness. In previous studies, blinking has been detected using EOG signal but this method is very annoying and obtrusive because it needs to stick electrode(s) to the driver's face. In this study we utilize a near field IR transceiver installed on the frame of the driver's eyeglasses as shown in Figure 1. When the user blinks, the output signal of the sensor changes. A readout circuit is designed to read the sensor value, amplify its output signal and eliminate its steady state value. The signal is then fed to the Arduino embedded system where it is converted to the digital form and compared to an adjustable threshold value.

In the Arduino board, we have the deviations of the head tilt angles and blink durations from its normal values and these normal values can be justified according to every driver's normal blink duration. Depending on the deviation values different scenarios may be used. For instance, the system can give a gentle alarm such as a short beep when either the blink duration exceeds a particular value or the driver's head is tilted. However, if both the head tilt angle and the blink duration show the drowsiness of driver the buzzer will alert the driver with a longer beep until both signs of drowsiness are vanished.

Figure 1: Schematic of position of the infrared on glasses

Circuit design

Neck angle measurement circuit

To measure the driver's neck angle, MMA7361 which is a 2D accelerometer is used. Front-back and left-right angle of the driver's neck axis with gravity axis of the earth is measured in this module and converted to voltage values in the output. Arduino board converts the output values of the accelerometer module to digital values and calculates the neck angle [Figure 2].

Infrared sensor readout sensor

Figure 3 shows the readout circuit of the IR sensor. Output of the sensor is passed through a 2-Grade high pass filter with cut-off frequency of 0.08 Hz. Then, it passes through a buffer and a 1-Grade low pass filter with cut-off frequency of 4 Hz. After that, the Arduino board converts this analogue voltage to digital value.

The appearance of the whole system circuits is shown in Figure 4.

The output values measured by the Arduino board to detect blinking from the output of the circuit which is shown in Figure 3 is depicted in Arduino serial monitor as shown in Figure 5.

Validation of the device

To validate the functionality of the designed system in neck angle and blinking events, two separate experiments were carried out. In the first experiment, the already verified software called Kinovea which is a free and open source tool based on image processing for distance and joint angle measurement is utilized as the reference.[26,27] It is used in research settings usually. Then, different angles of neck in two planes, namely the front-back plane and right-left plane, are simultaneously measured by the proposed system as well as the reference software. Screenshots of angle measurement in front-back head movements and

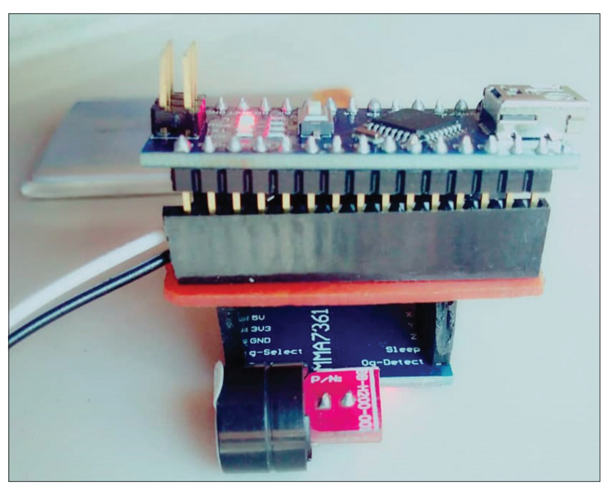

Figure 2: Shows the appearance of the designed circuit powered by a 1500 mAh lithium-polymer rechargeable battery

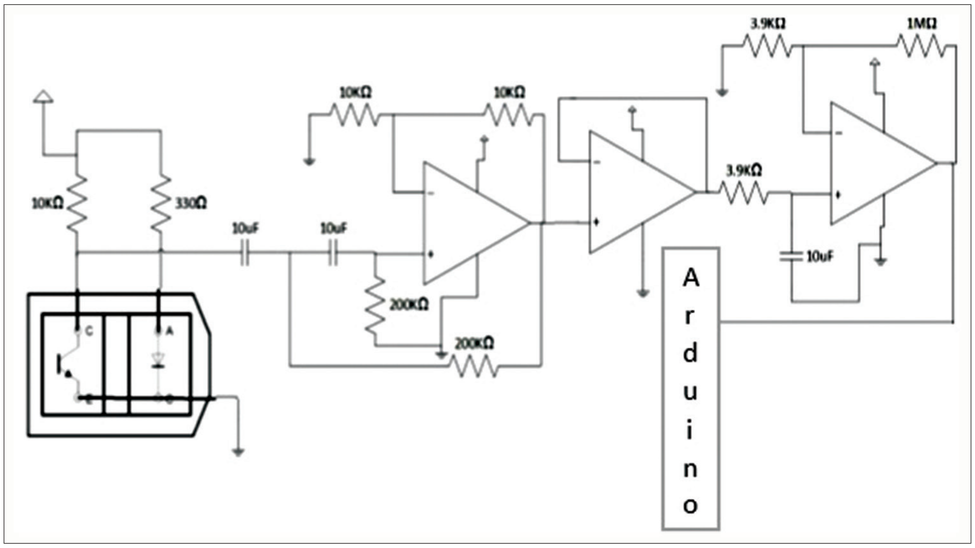

Figure 3: The readout circuit of the infrared sensor

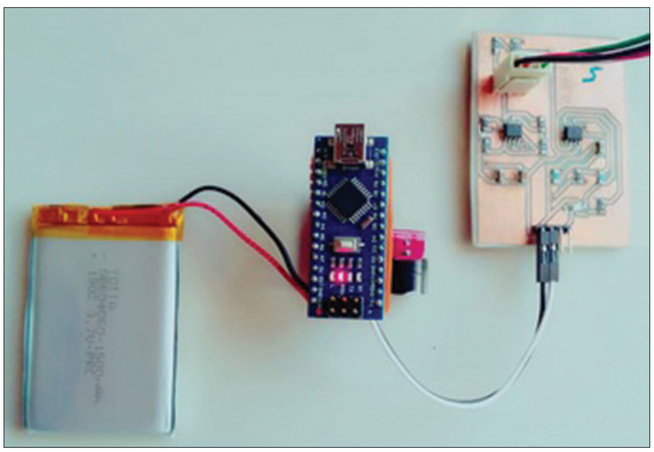

Figure 4: The appearance of the whole system circuits

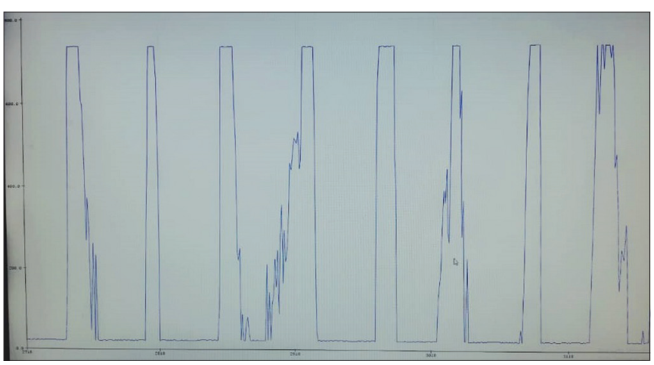

Figure 5: The output values measured by the Arduino board to detect blinking

right-left head movements using Kinovea software (It was made in the electronic lab of Baqiyatallah University of Medical Sciences, Tehran, Iran) is shown in Figure 6a and b. The measured angles using the proposed system is also transmitted to the computer and shown in a dedicated piece of software, which is developed in C#. A screenshot of the software is depicted in Figure 6c. The experiment was conducted ten times for one subject and the mean difference between the measured values in Kinovea software and our system was calculated to be ±2.3°. The good agreement between the results of the two system validates the functionality and the accuracy of the proposed system.

In the second experiment, the functionality of the blink detection system was validated by comparing the output of the proposed IR transceiver system with an EOG signal. Figure 7 compares the two signals, which are plotted using MATLAB. The comparison approves the efficiency of the proposed system for the detection of blinking. Thus, the proposed system can be considered as a low-cost and compact replacement for EOG method for blink detection.

Once the functionalities of the designed system for the detection of neck angle and blinking are separately validated, the last step is to verify the capability of the device alarm system for the detection of drivers' drowsiness. For safety reasons, this experiment cannot be carried out on a driver. Therefore, to validate the device, we conducted the experiment on a tired person while he was watching a movie on the screen of a laptop. During the experiment, the proposed system has detected the drowsiness of the person for 28 times. In all cases, the person under test has confirmed that he was about to fall asleep. More rigorous validations with advanced and relatively costly drowsiness detection systems can be subject of future studies. However, it should be noted that the purpose of this study is to develop an efficient cost effective and easy to use alarm system for the detection of driver's drowsiness in which installation of annoying and disturbing elements such as EOG sensors are avoided.

Discussion and Conclusion

In this study, we designed a system based on 2D accelerometer and IR sensor to measure the driver's neck

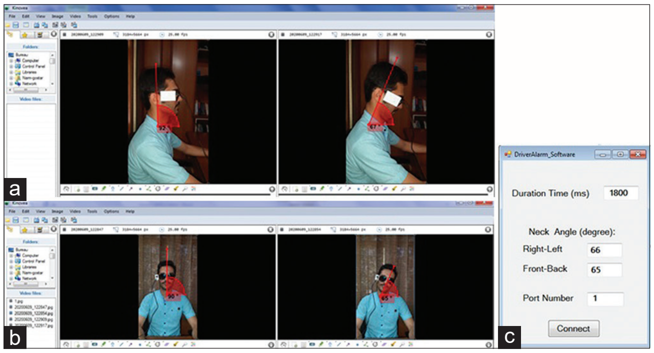

Figure 6: A comparison of neck angle measurement of the designed system and Kinovea software (a) Angle measurement in front-back head movement utilizing Kinovea software (b) Angle measurement in right-left head movement utilizing Kinovea software (c) The appearance of the designed C# software

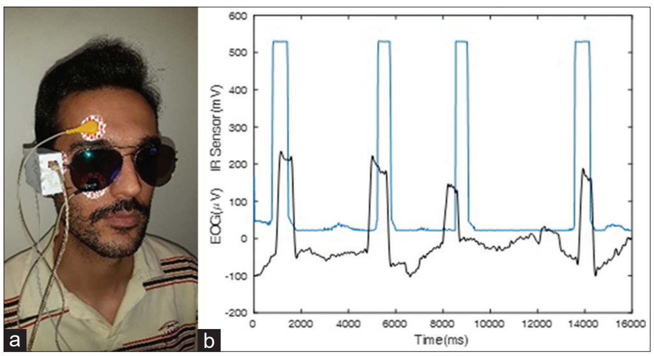

Figure 7: (a) Simultaneous electrooculography and infrared sensor recording setup (b) Simultaneous electrooculography and infrared sensor output plotted in MATLAB

angle and detect driver's blinking to realize the drowsiness of vehicle drivers and alert them using these signs of drowsiness. In the first grade, if just one of the drowsiness signs appear, a short beep will be made by the buzzer but if both of the drowsiness signs detected, the buzzer will make a long beep until the signs disappear to warn the driver.

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Conflicts of interest

There are no conflicts of interest.

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