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Development of a Drowsiness Detector based on the Duration of Eye closure using A Low-Cost EMG

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Abstract

Many traffic accidents are caused by drivers who are less concentrated due to drowsiness. From existing reports, it is known that the loss due to traffic accidents is very large, not only bring bad impact to the victims, also for the family environment, community and country. Seeing the conditions of this traffic problem, a device that can wake the driver while sleepy can be a solution. From several studies on drowsiness, it has been found that there is a connection between the drowsiness with blinking and closing the eyes often and long. This paper proposes a device that can detect the duration and frequency of eye closure using a low-cost EMG. When the accumulated duration of the eye closure exceeds the specified limit, a buzzer will sound to wake the driver. Compared to other detection devices, the low-cost EMG-based drowsy detector is promising, as it can be mounted practically on an eyeglass frame, and does not damage or injure the eyes. The development of this device so that it can be a reliable and economical device becomes an interesting challenge for the author and his team.

Keywords: traffic accidents, a drowsiness detector, an eye closure duration, a low-cost EMG, an eyeglass frame.

1. Introduction

The global status report on road safety that released by the UN WHO in 2015 states that deaths from traffic accidents around the world have reached 1.25 million per year, which means close to 3400 deaths every day. It is also reported that traffic accidents are the leading cause of death globally among people aged 15-29. Without proper effort, deaths from traffic accidents can be around 1.9 million per year by 2030 (WHO, 2015).

Traffic accidents have a terrible impact on individuals, communities and countries. It all causes not only grief and suffering, but also economic losses, productivity losses, reduced quality of life, and other social impacts (Soehodho, 2017; Sugiyanto, 2017).

Traffic accidents are often caused by three different factor types, namely, human error factors, vehicle factors, and external factors (including road conditions). Human error factors are the highest causal to traffic accidents, especially the lack of concentration due to drowsiness (Zuraida et al., 2017; Puspasari et al., 2015).

Drowsy driving is a major contributing factor to a traffic accident. This has been proven by the many studies that found a connection between driver drowsiness and traffic accidents. Preventing the driver from drowsiness will be able to reduce accidents. Physiological measures have frequently been used for drowsiness detection as they can provide a direct and objective measure. Possible measures are EEG (Electro-Encephalo-Graphy), eye movements, eye blinks and eyelid closure (Svensson, 2004).

EEG is an electrophysiological monitoring method to record electrical activity of the brain. EEG has shown to be a reliable indicator of drowsiness. The amount of activity in different frequency bands can be measured to detect the stage of drowsiness. The disadvantage of using EEG are the impractical placement of the device on the driver, and the obtrusive electrodes which make them unsuitable to use in cars, as cabling of the drivers would not achieve any acceptance (Mardi et al., 2011).

Eye movements can be measured using EOG (Electro-Oculo-Graphy). EOG is a technique for measuring the corneo-retinal standing potential that exists between the front and the back of the human eye. However, just like EEG, EOG has a weakness in the impractical placement of the device and the number of electrodes that must be put on the driver (Bandara, 2009).

Eyelid closure can be monitored with the camera very precisely and quickly. However, the use of the camera has a limitation of illumination, as the normal cameras do not work well at night when monitoring is more important. Other concerns for camera-based systems are the high cost and the loss of image when the drivers look in their mirrors outside the view of cameras. In addition, most of the camera-based system need computers, image processing algorithms and feature extraction techniques to extract drowsy symptoms (Garcia et al., 2010).

Instead of the camera, the eyelid closure can be captured using a portable and low-cost device based on IR sensors mounted on an eyeglass, that directing an IR beam to the human eye (Ma'touq et al., 2014). However, strong IR beam in high temperature could be harmful to eyes (Agrawal, 2017).

As an alternative drowsiness detection device, this paper proposes the use of a low-cost EMG (Electro-Myo-Graphy) to monitor the eyelid muscles, and measure the duration of the eyelid closure, then sound a warning when the duration exceed the limit.

2. Methods

2.1. Prototype of the Detector

In this paper, as mentioned earlier, a drowsiness detection device is proposed using a low-cost EMG, which is widely available in the local market under the name Myoware. To be able to measure the muscle electrical activity on skin, that has a very small voltage value (in µV unit), Myoware is equipped with 3 electrodes; 2 of them must be placed on skin in the measured muscle area, and 1 electrode must be placed on skin outside the muscle area, which is used as the ground point. All three electrodes can use any conductor material (Advancer, 2013).

The muscle to open and close the eyelids known as Levator Palpebrae, located at the top of the eye. To measure the tension in the muscle, 2 electrodes must be placed around the muscle, precisely in the upper eyelid, while 1 electrode can be placed outside the muscle, in the area close to the ear. The placement of a pair of EMG electrodes does not need to be pressed, just simply touching the skin. Therefore, the installation of a pair of electrodes can be done with the help of glasses, i.e. by placing it on the frame of the top glasses, such that when the glasses are worn, the pair of electrodes can touch the upper eyelid skin. The following figure is a prototype of drowsiness detection device that involves eyeglasses, electrodes, a Myoware Muscle Sensor, an Arduino Nano, a Potentiometer, a Buzzer and 2 Batteries.

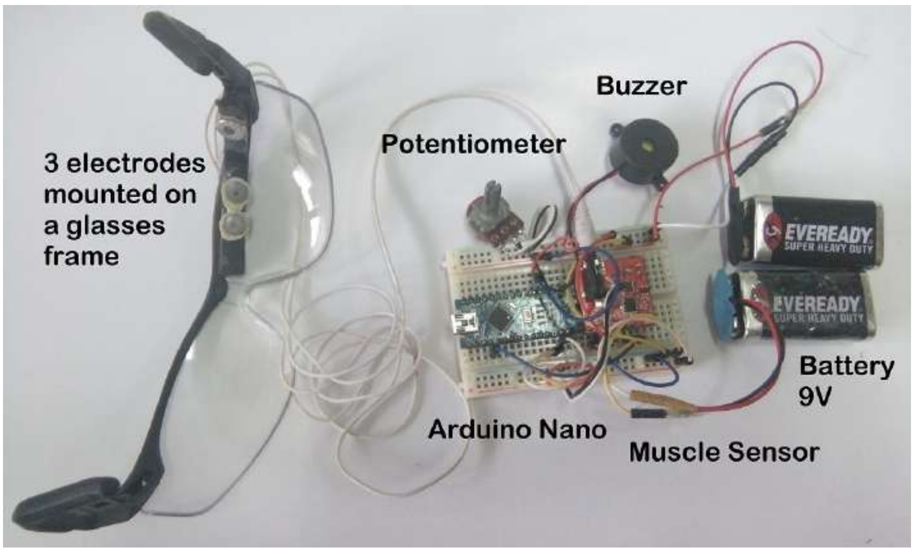

Fig. 1: The hardware prototype of drowsiness detection device

For more details about the circuit schematic of device and the placement of the three electrodes on the frame of eyeglasses, see Fig 2 below.

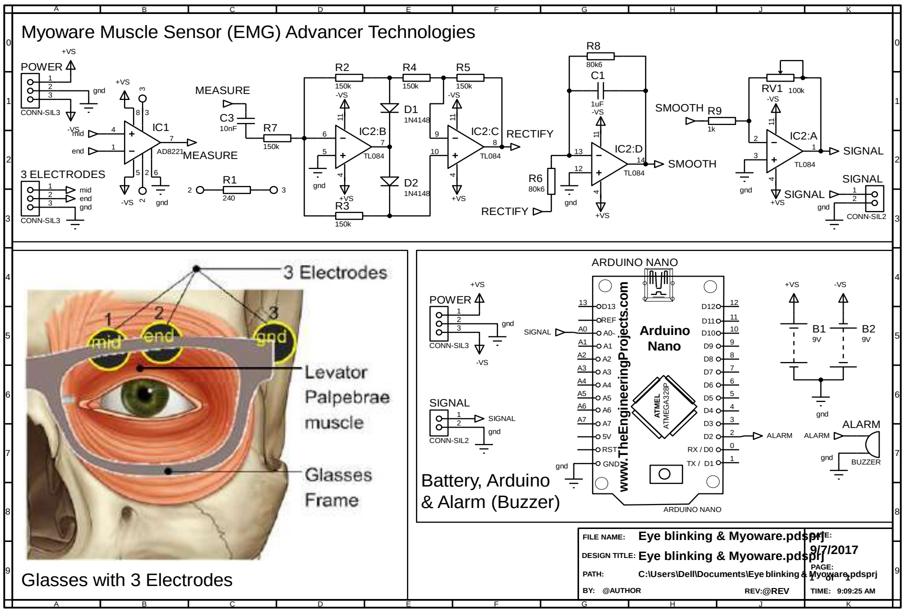

Fig. 2: Circuit Schematic and electrodes placement on eyeglass

Seen from Fig 2 above, a circuit schematic of the drowsiness detection device. The way this circuit works is, starting with an op-amp AD 8221 that measures a very small voltage difference between two electrodes placed in the eye muscle region. The result of the measurement is then rectified, smoothed and then amplified again to get the right value to be read Arduino. Using all the circuit, the Myoware sensor output value when the eyelid is opened is 0, and the output value when the eyelid is closed is greater than 0, and the value will be even greater when the eyelids are closed more tightly.

Fig 3 and 4 below show the graph of the eye muscle sensor output value using Serial Plotter Arduino when the eyelids are closed and when the eyelid are opened. It appears that the value of the graph curve becomes greater than 0 when the eyelid is closed, and is 0 when the eyelid is opened.

Fig 3: The graph when the eyelid is closed

Fig 4: The graph when the eyelid is opened

2.2. Prototype of the Alert System

After the Myoware sensor output value when the eyelid is opened and closed is known, the next step is to add an alert system so that the device can give a warning when a certain limit value is exceeded. To achieve this, a Buzzer and a Potentiometer have been added, as shown in the hardware prototype in Figure 1 above. The Buzzer here is used to generate warning sounds, and the Potentiometer here is used to set the time limit value of closed eyelid duration. Figure 5 below shows the block function diagram of the drowsiness detection system.

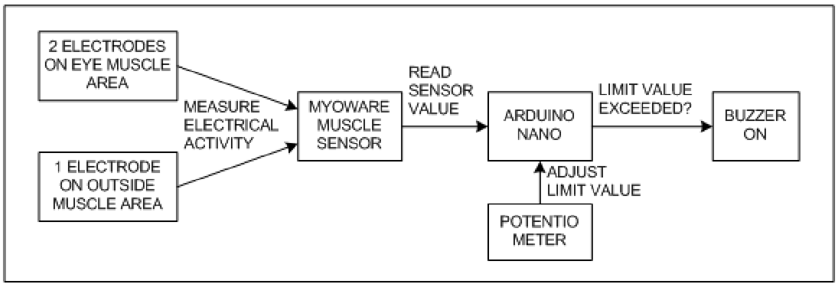

Fig 5: Function Block Diagram of Drowsiness Alert System

To achieve the function of the device following the function block diagram above, here is a more detailed state diagram of the working principle of the drowsiness alert system.

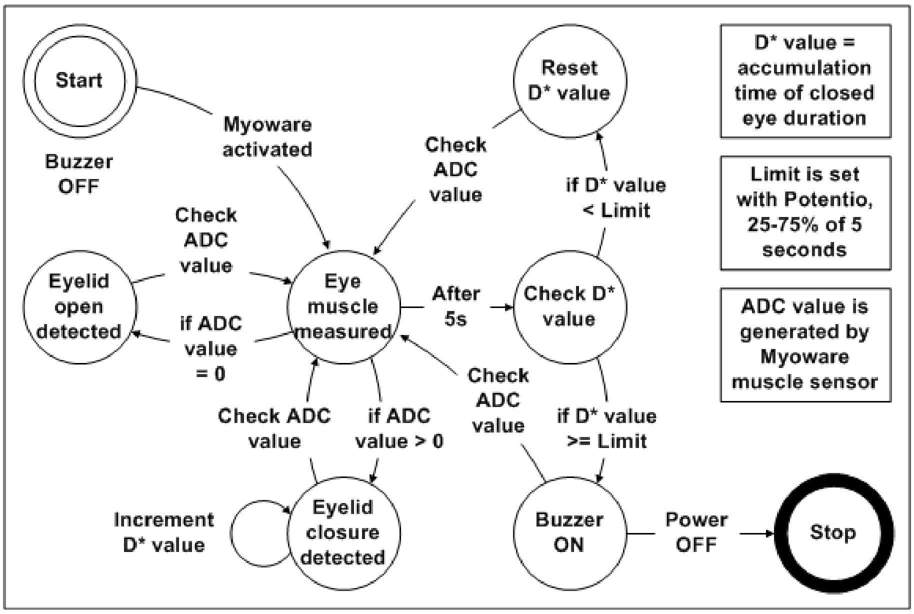

Fig 6: State Diagram of Drowsiness Alert System

Here is an explanation of the State Diagram above. Starting after Myoware is activated. It will get the value of eye muscle electrical activity. When the eye muscle is opened then the sensor value will be 0, and when the eye is closed the sensor value will be greater than 0. When the sensor value is greater than 0, a variable named D, will be incremented by 1. After 5 seconds, the value of D is compared with the time limit set by Potentiometer. If the value of D is greater than the time limit, then Buzzer will be sounded. If the value of D is less than the time limit, the value of D will be reset to 0. After the Buzzer sounds, Buzzer will continue to sound until the power supply to the device is stopped.

3. Results and Discussion

3.1. Results

From the methods of making the drowsiness detection device and the alert system proposed above, it has obtained the results of a portable and easily wearable drowsiness detection device.

Compared to the use of EEG and EOG, the device proposed in this paper is easier to install, because the electrode is installed only 3, so it can be placed on the glasses frame, while in EEG and EOG more than 3, so the use of EEG and EOG is perceived by the driver a little inconvenient, especially for motorcyclists. When compared with the use of cameras to monitor the eyes, the device proposed in this paper is better, because it is not affected lighting, both day and night. When compared to the drowsy detector using an IR beam directed directly to the eye, the device proposed in this paper is better, as it does not injure the eyes.

Another interesting thing, this device is quite economical, because EMG used is a very cheap type of EMG, also Arduino Nano, so the cost of making this device quite affordable. The result of making this tool is quite promising and can be developed to better meet the needs of users.

3.2. Discussion

To be discussed, the time limit setting of the closed eye duration is 25 - 75% of 5 seconds, i.e. 1.25 - 3.75 seconds. The time limit setting is determined by experience and reality on the highway, where for drivers who are driving at high speed, closing the eyes for more than 2 seconds can lead to a traffic accident.

The time limit value is deliberately made to have variations, due to different needs and levels of drowsiness. Some people have a habit of closing the eyes many times even if not sleepy. Some others may have experienced heavy drowsiness but did not close their eyes at all. So, for some cases, closing the eyes is not directly related to drowsiness. It is necessary to observe the habit before wearing this device. However, in general, if a person initially rarely closes and blinks his/her eyes, then after a while becomes frequently closes and blinks it, then this can be a sign that the person is sleepy. So, a change of pattern from closing the eyes suddenly and often can be a sign that there is drowsiness.

4. Conclusion

In this paper, a prototype of drowsiness detection device using cheap and easy-to-wear EMG has been proposed. From the observation results, this device is quite promising because of the following points:

1. The use of closed eye duration indicator has a better chance of detection, because the results are quickly known so that it can give warning more quickly when the driver is sleepy.
2. Use of EMG is better than EEG and EOG, because the number of EMG electrodes is less, so it is not complicated to be mounted on the glasses frame.
3. Use of EMG is better than cameras and IR sensors, because it is not affected by daylight or nighttime light, and does not injure the eyes.

In closing, this proposed device still needs to be developed, because for some people, even if they often close and blink their eyes, it does not mean they're sleepy, but because they're used to such reflexes. But if the person rarely blinks and closes his eyes, then after some time becomes often blinks and closes his/her eyes, then this condition can be a sign of the person is sleepy. These specific conditions need to be considered for the development of this device in the future.

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