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Detecting Drowsy Driver Using Pulse Sensor

Herlina Abdul Rahim[a*], Ahmad Dalimi[a], Haliza Jaafar[b]

[a]Protom-i Research Group, Infocomm Research Alliance, Control and Mechatronic Engineering Department, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Language Academy, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

*Corresponding author: herlina@fke.utm.my

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Graphical abstract

Abstract

The driver's condition, which involves staying focus on the road, is the most important aspect to consider whenever one is driving. To ignore the importance of this could result in severe physical injuries, deaths and economic losses. Again, previous researches were focused mainly on the physical conditions of the driver; eg movement of head and drowsiness. However, this research is focused on the driver's heart rate by using an infrared heart-rate sensor or pulse sensor. These sensors are non-intrusively measured heart pulse wave from the driver's heart. By doing experiment, the results show clear pulse wave signal can be obtained by looking at the low to high frequency (LF/HF ratio) which calculate HRV frequency domain of the driver's heart rate time series. The LF/HF ratio shows decreasing trends as the drivers go from the state of being awake and alert to the state of drowsiness. Therefore, accidents can be avoided if there is an alert system to keep the drivers alert and focused on the road.

Keywords: Pulse sensor; driver rate; accidents; drowsy

1.0 INTRODUCTION

There were approximately 27 million drivers on Malaysian roads today. The Department of Traffic and the Road Safety Department (2012) reported that there were about 17288 car accidents, which were caused by drowsy drivers. These accidents caused approximately 2000 fatalities and 7432 nonfatal injuries every year. Again these supported the fact that the causes for these unfortunate calamities were the drivers being drowsy while driving.

Naturally, a drowsy or sleepy driver normally will lose control of the vehicles and as a result where will be accidents, fatalities or casualties. Based on these occurrences, many researches were carried out to focus on the driver's physical and mental condition while driving on the road.

Review of Drowsiness Detection Techniques

The following techniques or measures have been developed and used widely to monitor the level of drowsiness of the driver by vehicle-based measures, behavioral and psychological measures [1-5].

1) Vehicle-based Measures

The first measure is vehicle-based measures; which mean a number of metrics, including deviations from lane position, movement of the steering wheel, and pressure on the gas pedal which are constantly monitored and any changes in these that crosses a specified threshold indicates a significantly increased probability that the driver is feeling drowsy.

2) Behavioral Measures

The second measure is behavioral measures that detect the facial movement of the driver, including yawning, eye closure, eye blinking, and head position. They are monitored through a camera and the driver is alerted if any of the drowsiness symptoms are detected.

3) Physiological Measures

This approach is to measure physiological changes of drivers from biosignals, such as the electrooculography (EOG), electroencephalogram (EEG) and electrocardiogram (ECG or EKG). Physiological signals are more suitably used to detect drowsiness because the sleep rhythm is strongly connected with brain and heart activities. However, normally electrodes will be used on the person's head, face and chest with an abundance of wires protruding everywhere and these irritate the person and make it hard to implement the system.

Review of Heart Rate Signal Measurement

ECG is a test that records the electrical activity of the heart [5]. It will give information regarding the rhythm of heart. An ECG requires the electrodes contacts, which are attached to human body (arms, legs and chest) by using coupling gel. This physiological signal is a portable unit or machine that can be used in or outside of medical premises and whoever needs medical assistance to monitor and analyze physiological signals. [3]. Moreover, an ECG is painless because no electricity is sent through the human body [5].

ECG also uses non-invasive method which the pulse wave of heartbeat measures the variation in blood volume in tissues using light source and a detector.[6, 7]. This method uses an infrared sensor as both the infrared light emitter diode and the detector are arranged side by side in a leaded package. It is important to block the surrounding ambient light, which could affect the sensor performance. Most of the light is absorbed and reflected by our organs and tissues (skin, bone, muscle, blood), but some light will pass through our tissues if they are thin enough [8].

In our research, we use pulse sensor that used infrared emitter and detector diode to get the ECG signal and then it is implemented on the steering wheel as shown in Figure 1.

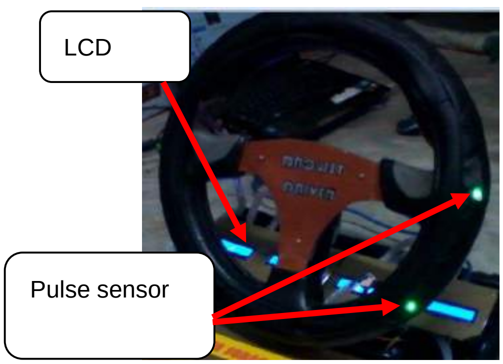


Figure 1 Pulse sensor on steering wheel

This technique is based on the principle of photoplethysmography (PPG) that uses two basic types, which are transmittance and reflectance [6]. The two basic type of PPG can be used because adult human bodies such as fingers, cheek, hand, are semi-transparent. In transmittance PPG, a light source is emitted into the tissues and a light detector is placed in the opposite of the tissue to measure the resultant light. While in reflectance PPG, the light source and the light detector are both placed on the same side of a body part which the light will be emitted into the tissues and it will reflect to the detector. Because the light does not have to penetrate the body, the reflectance PPG can be applied to any parts of human body and it is suitable to use for this project.

The theory is applied when the blood is pumped through the body, it gets squeezed into the capillary tissues and the volume of those tissues will increase very slightly [7]. Then, the volume decreases between heartbeats. So, the amount of light emit is absorbed depending on the tissues blood volume. Consequently, the reflected light intensity varies with the pulsing of the blood with heartbeat. This fluctuation can be seen when a plot of this variation against time is produced.

2.0 METHODOLOGY

Configuration of Pulse Sensor

The configuration of the proposed pulse sensor is illustrated in Figure 2. The pulse sensor was installed around the inner circle of the steering wheel to measure heart pulse wave, which can ensure the detection even with single hand driving. Each sensor unit has a pair of infrared emitter and detector diode that placed side by side to detect clear ECG signal.

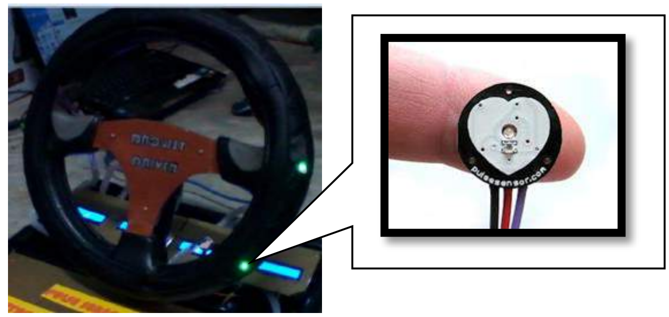


Figure 2 Configuration of the pulse sensor on steering wheel

Liquid Crystal Display (LCD)

Liquid Crystal Display, which is commonly known, as LCD is an Alphanumeric Display displays Alphabets, Numbers as well as special symbols. This makes LCD a user friendly. Display device which can be used for displaying various messages; unlike seven segment display which can display only numbers and some of the alphabets. The only disadvantage of LCD over seven segment is that seven segment is a robust display and can be visualized from a farther distance as compared to LCD. We have used 16 x 2 Alphanumeric Display which means on this display, we can display two lines with maximum of 16 characters in one line. LCD is used to display and monitor the heartbeat of the driver.

Features
Operate at 5V
Uses Arduino LCD 4Bit library
Plug and Use with Arduino main board, no solder or fly-wiring needed
2x16 LCD.

Vibrator

Vibrator is a device that vibrates when it is plugged in low voltage 5V. It is used as the output of the system. The vibrator, which is installed in the driver's seat, is preferred to buzzer because the buzzer produces (buzzing) sound which annoys the driver and makes him uncomfortable to continue driving. When the driver starts to feel drowsy, the Arduino Uno microcontroller will turn the vibrator ON as to alert the driver.

Driving Stimulation

A driving simulator is used to test the drowsiness detection system. The simulator has a screen to display the virtual reality driving environment, a real-size driver seat and a steering wheel with pulse wave sensors. Two subjects are male and female who were asked to drive with the simulator non-stop for two hours. The subject's heart rate was continuously recorded by the heart pulse sensors installed on the steering wheel. A camera was used to capture the video of driver's behavior. The video will serve as a reference for the driver's level of drowsiness.

■3.0 EXPERIMENTAL RESULTS

The main aim of the experiment was to get the value of beat per minute (BPM) and HRV frequency domain for normal stage and level of drowsiness of the driver. The experiment was carried out on two subjects; a male driver and a female driver. It was very important to identify the difference rate of their heartbeats.

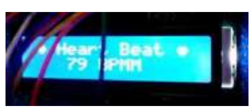
Beat per Minutes (BPM)

One of the results that was recorded was the BPM of the drivers; in normal stage and in state of drowsiness. Two experiments were run on both subjects; the male and female driver.

In that experiment, the pulse sensor was attached at their finger while they were in normal stage condition and drowsiness stage condition. In the normal stage condition, they were in condition at rest and do not do the kind of work, which will make their heartbeat beat rapidly. It was very important to know that when their heartbeat was at normal condition, it was easy for the data to be analyzed. Table 1, the heartbeat for the male driver was around 75 to 100 BPM while for the female driver was about 70 to 95 BPM. There was a difference between male and female heartbeat because male's heartbeats faster than female's heart.

The experiment was carried out when they were being tired after went through all activities the whole day without any asleep such as to focus on their study. This was important to get the best result for drowsiness stage condition. If the subject was extremely drowsy, their BPM will decrease rapidly. So, in this case, we just focused on the subjects at early drowsy stage condition. In Table 1, the male's BPM was between 50 to 65 BPM while the female's BPM was around 45 to 63 BPM.

Table 1 BPM results for 2 subjects

Type of stages	Male	Female
Normal	 75BPM < BPM <100BPM	 70BPM< BPM <95BPM
Drowsiness	 50BPM < BPM <65BPM	 45BPM <BPM <63BPM

Processing HRV Frequency Domain

Processing software was used in this experiment to collect the frequency band in both stage conditions which is normal and in the state of drowsiness. The experiment was carried out while the two subjects driving the simulation in two hours. Both results were shown at Figure 3 and Figure 4.

Normal Stage Condition

In normal stage condition, we can see that the value of the HRV frequency domain was 0.700 Hz. It was a high frequency band.

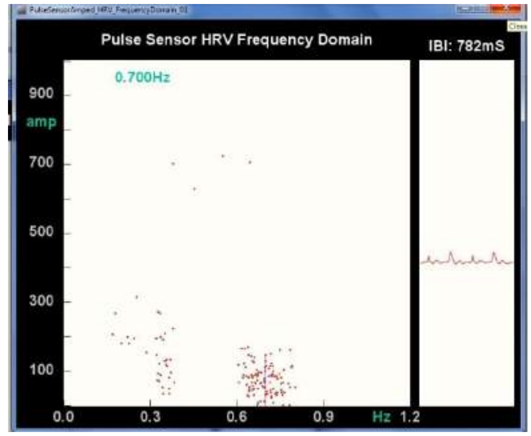


Figure 3 HRV frequency domain for normal stage condition

Drowsiness Stage Condition

In the drowsiness stage condition, we can see that the value of HRV frequency domain was 0.183Hz. It was a low frequency band.

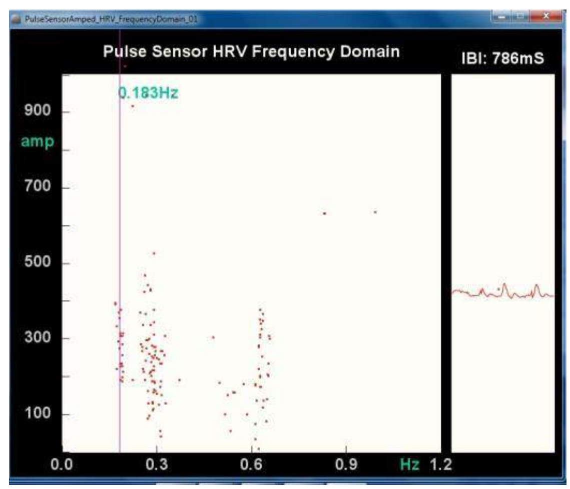


Figure 4 HRV frequency domain for drowsiness stage condition

During the two hours in simulation driving, the data was collected and recorded every 10 minutes and calculated the ratio of low frequency band over high frequency band (LF/HF). The data has shown in Table 2.

Table 2 LF/HF ratio data collected in 10 minutes after 2 hours

Time (minutes)	Drowsiness (Hz)	Normal (Hz)
1	0.189	0.453
2	0.176	0.443
3	0.158	0.339
4	0.168	0.367
5	0.157	0.385
6	0.164	0.451
7	0.169	0.422
8	0.152	0.417
9	0.175	0.375
10	0.15	0.486

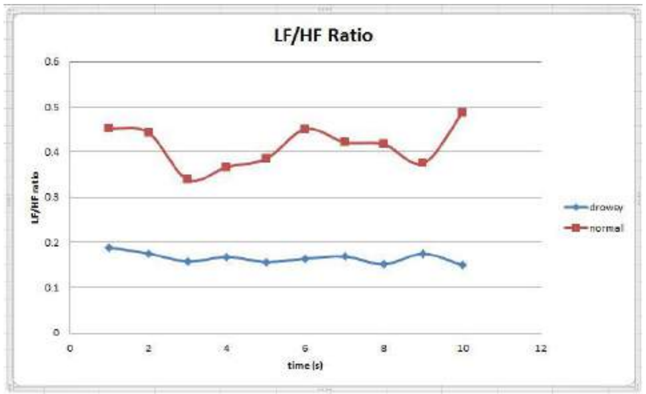


Figure 5 Drowsiness versus normal stage

In Table 2, the results show clear pulse wave signal can be obtained by the HRV frequency domain of subject's heart rate time series (the low to high frequency (LF/HF ratio). The LF/HF ratio shows in Figure 5 decreased as the drivers went from the state of being awake to being drowsy. So a number of road accidents could be avoided if an alert is sent to a driver who seems to be getting drowsy while driving..

■4.0 CONCLUSION

As a conclusion, we have reviewed the various methods available to determine the drowsiness state of a driver. Although there is no universally accepted definition for drowsiness, the various definitions and the reasons behind them were discussed. This paper also discusses the previous researches that were done in many types of sensor in detecting drowsy driver by using ECG signal. By using the physiological measures to detect drowsiness, the accuracy rate is high and highly intrusive. This intrusive nature can be resolved by using contactless electrode placement. In addition, it is important to consider the driving environment to obtain optimal result.

The goal of this project is to design a system that can alert the driver by detecting their heartbeat using pulse sensor and by wiring to Arduino Uno microcontroller. These sensors are non-intrusively and they measure heart pulse wave from the driver's finger or hand. The sensor was used on the driver's finger or hand, detecting the amount of blood, which is flowing through the driver's finger. The amount of oxygenation of the blood is shown in the finger, which caused the infrared light to reflect off the skin and to the transmitter, which is close by. The sensor picks up the fluctuations of oxygenation, which are wired to the Arduino as microcontroller for this project. Then, the heart pulse wave was visualized by using Processing.

By doing the experiment, the results shows clear pulse wave signal which can be obtained by the HRV frequency domain of driver's heart rate time series (the low to high frequency (LF/HF ratio) The LF/HF ratio shows a decreasing trends as drivers go from the state of being awake to being drowsy. So a number of road accidents could be avoided if an alert is sent to a drowsy driver.

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