Development of non-invasive alcohol analyzer using Photoplethysmographytle

Pornnapa Sanguansri, Nattapat Apiwong-ngam, Athipong Ngamjarurojana and Supab Choopun*

Applied Physics Research Laboratory, Department of Physics and Materials Science
Faculty of Science, Chiang Mai University, Chiang Mai, 50200, Thailand

* Corresponding author's e-mail address: supab.c@cmu.ac.th

Abstract. Photoplethysmography (PPG) is one of the optical signals commonly used in clinical research for measuring the vital signs. Previously, PPG is often used as an indicator for detecting blood volume changes in the micro-vascular. The advantages of PPG signal mentioned in studies are non-invasive, lower operation cost, and the simplicity of the procedure. Although some the components of the PPG signal are not fully understood, it is generally accepted that it can provide valuable information in clinical study. Thus, it is interesting for finding a relation between PPG signal and blood alcohol concentration. The objective of this study is to classify two groups of ten-volunteer: (1) group of people who consumed alcohol and (2) non-consumed alcohol, by using the difference of PPG signals in these two groups and compared the results with fuel-cell breath alcohol analyzer. A set of PPG reflection data is recorded from optical sensors including the wavelength light of the red light and the infrared light from the fingertip of individuals. In additional, the changes of each signals for distinguishing two groups of volunteers are examined. The set of data is computed and analysed to find the correlation coefficient between significant variables in statistic domain. The analysis techniques are included (1) slope of the signals over time, (2) peak to peak of the heart rate, and (3) deep of waveform valley after rotation for training generalized linear (GLM) classifiers to create classification models. The accuracy of GLM classification can be obtained up to 87.50%. This suggests that PPG technique with our lab prototype has a potential for screening test to classify people who consumed alcohol and non-consumed alcohol.

1. Introduction

Driving under the influence (DUI) of alcohol is a major traffic accident for Thailand in the past decade. It is a leading cause of injury and death, especially, during the major festival such as Songkran festival or New Year festival. In 2021, according to The Road Safety Operation Center (RSOC) during the "Seven Dangerous Days" of the New Year, drunk driving cases accounted for nearly 33% of all traffic accidents. One solution for reducing the death rate of DUI in Thailand is limited to a minimum blood alcohol concentration (BAC) per legal at 0.05 percent [1]. Typically, two methods can be used as indicators for a BAC, breath test and blood test [2]. The blood test can be directly evaluated and more accurate. There are some drawbacks such as invasive methods, too many steps, and the need for experts

for measuring. The breath test is commonly used for estimation BAC because of non-invasive and immediate results. Due to the epidemic COVID-19, these two methods are inconvenient, increase workload and procedure in medical, expand risk to contaminate COVID-19, and concern hygiene. Therefore, the PPG technique is an alternative way to investigate BAC. In brief, PPG is an optical technique that measures at the surface of the skin to detect volumetric changes in blood through the change in light absorption or reflection. PPG can be used to detect vital signs. Typically, it is used to measure blood oxygen levels and heart rate [3] with the benefits of non-invasive, inexpensive, convenient, and easy to merge with portable devices. It has been reported [4,5] that PPG has been used to measure BAC of the driver. So, this study aims to classify the person who consumed and non-consumed alcohol using the difference of PPG signals in these two groups and compared the results with a fuel-cell breath alcohol analyzer. The PPG signals are obtained from the reflection light of red and infrared light onto a finger.

2. Experimental

2.1. Device design and data collection

The primary PPG signal is collected by our lab prototype as shown in figure 1. The volunteers put the finger on the finger clip during the test. Each volunteer is controlled to consume the same amount of a bottle of 650 ml. beer with a 5% of alcohol. However, the amount of BAC of each volunteer does not expected to be the same due to the difference in gender, weight, and body metabolism. The PPG signals are obtained from the LED of red and infrared light. The PPG signal is processed by the Arduino zero SAND21, and the PPG is analysed by the spreadsheet software. The collected signal has band pass filter for noise reduction. The process of collecting data considered in this research is shown in figure 2.

Figure 1. Our lab prototype that designed for this experiment.

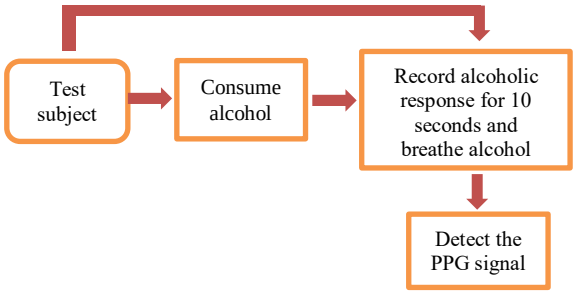

Figure 2. Flowchart of the data collection.

2.2. Processing a datum line rotation

Analytic data is measured for observing different signals from before and after consuming alcohol of the volunteers by using the Datum line rotation process. The primary part from PPG signals for the analysis is the maximum and minimum value of the waveform and is selected using a spreadsheet software.

In the datum line rotation [6] for this research, there will be a total of four procedures. The first step will be to estimate the maximum and minimum points of the peak as shown in figure 3 (a). Then the second step, a datum line is created as shown in figure 3 (b). A linear extracted from the maximum to the minimum can be indicated as in the equation (1).

$$y = mx + c \tag{1}$$

Next, the waveform signal is rotated with an angle until the datum line becomes a horizontal line as seen in figure 3 (c) and as shown in equation (2).

$$\theta = \tan^{-1} m \tag{2}$$

Finally, the new points are created by rotating the primary points using the equation (3)

$$X' = X\cos\theta + Y\sin\theta$$
$$Y' = -X\sin\theta + Y\cos\theta \quad (3)$$

Thus, the datum line rotation can be defined as a rotation of the datum line created from the maximum and minimum points of the PPG waveform until the datum line becomes a horizontal line.

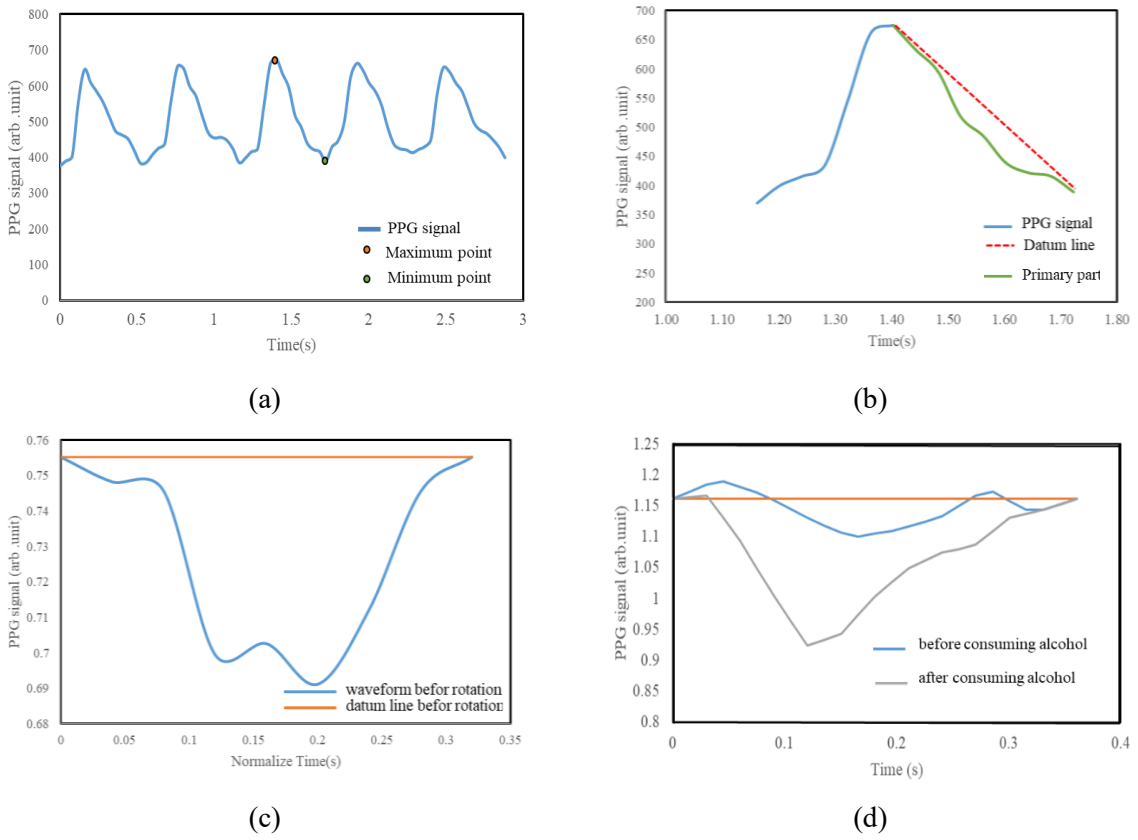

Figure 3. Datum line rotation procedure. (a) PPG signal indicating maximum and minimum point (b) datum line is created from the maximum to the minimum point (c) waveform signal is rotated with an angle until the datum line becomes a horizontal line (d) PPG signal after rotation for before and after consuming alcohol.

2.3. Prediction and classification

The statistical is analyzed by Package Program (R studio) to create a predictive model and classification. The data has been divided into two groups of PPG signals; before and after alcohol consumption. GLM classifiers is used for classification.

3. Results

3.1. Device design and data collection

The volunteers placed a finger on the finger clip for a stable measurement of PPG signals. PPG signals are plotted as a function of time. After band-pass filter, the PPG signals looks close to the waveform that is easier for analysis.

3.2. Processing a datum line rotation

The features of the datum line rotation generated for analyzing data are shown in table 1.

Table 1. The feature of datum line rotation generation

Feature	Description of feature
m	The slop of datum line linear extract
d	The maximum depth of waveform after rotation
sumpos	The sum of the depth under the datum line the waveform after rotation.
IR	PPG signal from IR LED
Red	PPG signal from red LED

The consistency of datum line rotation can be demonstrated by the standard deviation (SD) of the parameter, which is relatively low for each set of data. For example, the SD of dIR parameter of one volunteer is about 0.0158 with the mean of 0.176.

In addition, the results after the datum line rotation of 4 volunteers are shown in table 2. Most of the waveform after consuming alcohol shows the higher depth of waveform than that of before consuming alcohol. Figure 3 (d) shows an example of the different waveforms of the PPG signal of the volunteers (27-year-old female) before and after consuming alcohol.

Table 2. The result of datum line rotation generation.

Data		Subject 1		Subject 2		Subject 3		Subject 4	
		before	after	before	after	before	after	before	after
IR	sumpos	0.666	1.208	1.77	0.724	1.45	1.523	0.519	1.045
	d	0.071	0.122	0.149	0.063	0.15	0.156	0.069	0.122
	m	-644.7	-562.73	-2242.3	-3357.1	-605.85	-1154.7	-291.04	-487.21
RED	sumpos	1.068	1.165	1.424	0.724	1.238	1.61	0.618	1.294
	d	0.134	0.137	0.134	0.066	0.169	0.163	0.111	0.181
	m	-89.71	-200.92	-720.38	-981.35	-237.39	-438.27	-169.61	-203.27

3.3. Prediction and classification

After collecting the PPG signals of 10 volunteers before and after consuming alcohol for two times, the PPG signals of 40 set are obtained. The data are forwarded to the R studio for creating a predictive model and classify before and after consuming alcohol. It is found that 80 % of the collected data are splitted into a training set and 20 % into a testing set by using three features from analysis; for training GLM classifiers to create classification models. The main features for an alcohol classification are three parameters, including dIR, sumposRed and mIR. These parameters are selected from the statistical analysis using R studio with the p value less than 0.10. The p value of dIR, sumposRed and mIR is 0.0451, 0.0871, and 0. 0.0997, respectively. Before consuming alcohol, data is marked as the class “0” while after consuming alcohol, data is marked as the class of “1”. Moreover, the best accuracy of classification is observed at 87.50%. The accuracy is calculated from the number of the volunteers that GLM classification can correctly predicted and divided by the total number of volunteers. For the best accuracy, the correct prediction is 7 out of 8 volunteers. This suggests that the PPG technique has a potential for detecting alcohol in blood.

4. Conclusion

The non-invasive alcohol analyzer by using PPG is successfully developed. The classification of the person who consumed and non-consumed alcohol using the difference of PPG signals in these two groups and compared the results with a fuel-cell breath alcohol analyzer can be achieved. The key features of PPG signals are dIR, sumposRed, and mIR for training GLM classifiers to create classification models. The accuracy of GLM classification can be obtained up to 87.50%. This suggests that PPG technique with our lab prototype has a potential for screening test to classify people who consumed alcohol and non-consumed alcohol.

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