The Study of PPG and APG Signals for Biometric Recognition

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***Abstract*—Nowadays, the numbers of identity theft victims are increasing year by year and caused financial losses. This issue needs to be dealt with before it becomes worst. Many ways has been done in order to decrease the number of identity theft victims. For examples, password is needed in order for the valid user to access the applications or services and identifications card are used for entry in premises. However, these approaches have limitations such as easy to be forgotten and lost. Recently, bio-signals are getting attention among researchers since it marks our vital parts of the body and used in the unimodal biometric system. Therefore, this study proposes of a more secure mechanism by using PPG and APG signal for biometric recognition system. PPG signals data will be collected from 10 different subjects by using an Easy Pulse sensor data acquisition device. Then, in order to obtain APG signals, the process of signal transformation was conducted. Next, preprocessing was applied to remove the unwanted signal or noises. After that, the features of the PPG and APG signals were extracted. Finally, these PPG and APG samples undergo the classification process by using classifiers to identify individuals. Based on the experimentation results, PPG signal obtained 84% identification rates as compared to the result 94% of APG signal when using Bayes Network. The next classifier used is Multilayer Perceptron (MLP) which gives result of 84% and 92% of PPG signal and APG signal respectively. The other two classifiers used are Sequential Minimal Optimization (SMO) and K-Nearest Neighbors (IBk). The achieved result for PPG signal is 90% while for APG signal the result is 96% when using SMO classifier. Lastly, the obtained result for IBk classifier is 92% for PPG signal and 94% for APG signal. The outcome of this project proved that multimodal biometric can be performed by using PPG and APG signal since everyone has different PPG and APG signal.**

***Index Terms*—APG; Multimodal Biometric; Person Identification; PPG.**

I. INTRODUCTION

In the United State of America (USA), approximately 15 million residents have their identities misused every single year and caused around $50 billion financial loss [1]. There are so many systems in this world that require personal recognition and the purpose of these systems is to make sure that the services only can be accessed by legitimate users. However, these systems still can be accessed or hacked by impostors. One the alternative to current recognition system is biometric. Biometric recognition or biometric refers to the automatic authentication or statistical analysis of individuals that is based on the individual's physical or behavioral characteristics. A biometric system is use to identify the identity of a person that operates by collecting biometric data from an individual, extracting the feature sets and comparing these discriminative feature set with the template set in the database.

Nowadays, biometric system based on photoplethysmogram (PPG) signal has been developed. Moreover, there is another signal which is acceleration plethysmogram (APG) signal that can be analyzed and has potential for biometric identification. This waveform is initiated from the PPG signal where it is the second derivative of PPG. Therefore, this study investigates the relationship of the PPG and APG signals in biometric recognition. With the identity crime, it is significant strengthen the present security methods which is by using a multiple biometric scheme called multi-biometric system.

II. LITERATURE REVIEW

There are various techniques of analyzing PPG and APG signals. In this literature review, it is more focused on the PPG and APG signals for biometric recognition. There are many ways to analyze the PPG and APG signals to identify the identity of a person.

A study by Gu et al. in [2] proposed a human verification approach using PPG signals that can be obtained easily from the fingertip. The experimentation of this study was performed by examining the PPG signal characteristics. As a result, only one out of the 17 different subjects could not be verified properly, which generated a 94% of successful rate. However, the PPG signal of a human can be distracted due to the different physical condition and different weather.

Moreover, Jaafar et al. in [3] proposed an Acceleration APG based biometric identification system. From the PPG signal second derivative, the APG signals can be obtained. The result of experiment APG signal obtained 97% identification rate as compared to the result 55% identification rate of PPG signal for the same waveform. Thus, this result recommends the usefulness and robustness of APG signals as a biometric identification process as compared to PPG signals. However, error of this system can occur if the subject is not relax and has irregular heartbeats.

As a conclusion, out of these studies only focuses more on single level biometric identification. Thus, this study is about the multi-level biometric system based on PPG and APG signals where there is another biometric system to valid the identification and will increase the security of the biometric data of the subjects.

III. METHODOLOGY

The multimodal biometric system will secure the identity of a person since there are two levels in identifying a person's identity. There are many steps in this system that has been chosen to recognize identity of a person as shown as in Figure 1.

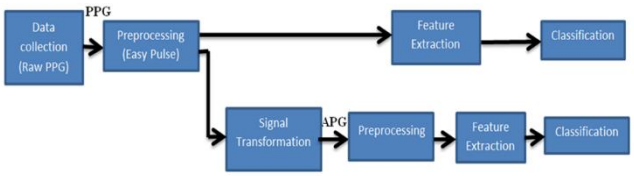


Figure 1: Multimodal biometric system methodology.

A. Data Collection

Data collection is the first process of this proposed system. In this step, the raw PPG signals were acquired from 10 different subjects with 60 seconds duration from an Easy Pulse sensor device. This device was attached to the subject's fingertip for the measurement and obtaining the PPG signal.

B. Preprocessing (Easy Pulse sensor)

After the PPG signals were obtained, these data signals need to go through preprocessing which to remove additional noise in the waveform. Therefore, high pass and low pass filters with cutoff frequency of 0.5 Hz and 3.4 Hz respectively [4], were applied to remove the noise in the signal which already included in the Easy Pulse sensor circuit.

C. Signal Transformation

The process of signal transformation was performed by using the second derivative of PPG signal. After collecting the raw PPG signals, this step was required to obtain the APG signal by differentiating the PPG data. The mathematical expression [5] for this step is shown as in Equation 1.

$$\frac{d^2y}{dx^2} = \frac{d}{dx}\left(\frac{dy}{dx}\right) \quad (1)$$

D. Preprocessing

After the APG signals were obtained, these data signals need to go through preprocessing. The additional noise existed after the signal transformation process. This method was applied to eliminate unwanted signal in the waveform as it will affect the result in identifying a person's identity. Therefore, Butterworth filter with normalized cutoff frequency of 0.25 Hz was used to remove the noise in the signal.

E. Feature Extraction

This feature extraction process can be categorized in two different phases. The phases were segmentation and normalization.

a. Segmentation

The signals were segmented based on the criteria of the amplitude waveform. This segmentation phase was to determine the maximum and minimum point of the signals to define one PPG and APG cycle.

b. Normalization

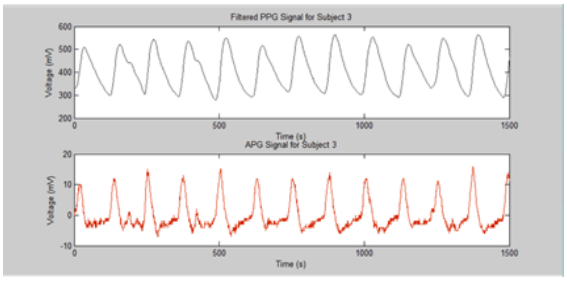
After the segmentation phase, the normalization was applied. This phase was used to destroy completely the received noise to make a starting point for comparison from the PPG and APG signals by leveling it to the same signal scale.

F. Classification

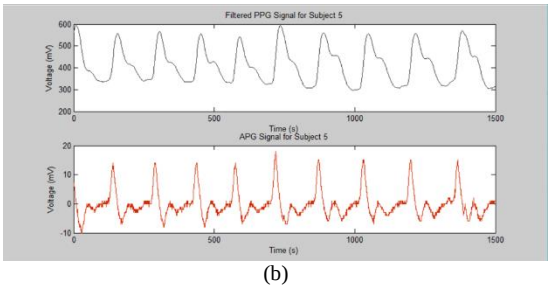
Classification is the last procedure of this system which used to classify the characteristics of a person's bio-signals which are APG and PPG signal in order to identify the legitimate user. There are many classifiers that were used for this process which are Bayes Network, Multilayer Perceptron (MLP), Sequential Minimal Optimization (SMO), and K-Nearest Neighbors (IBk).

IV. EXPERIMENTATION AND RESULTS

10 different samples were acquired from 10 different subjects was the first process which is data collection with duration of 60 seconds by using Easy Pulse sensor device. However, the PPG data signals have been filtered by using high pass and low pass filters. This process is called preprocessing. Next, signal transformation was performed to obtain APG signal from the second derivative of PPG signal. The results of filtered PPG and raw APG signals from subject 3, 5 and 7 are shown as in Figure 2(a) until Figure 2(c). It can be observed that different people have different waveform of PPG and APG signals.



(a)



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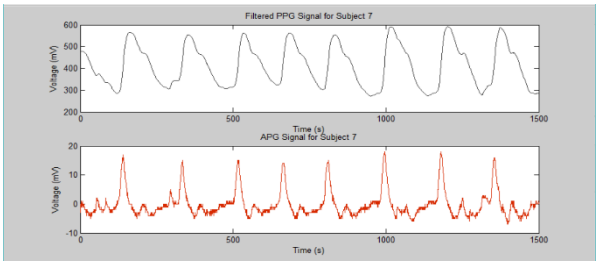
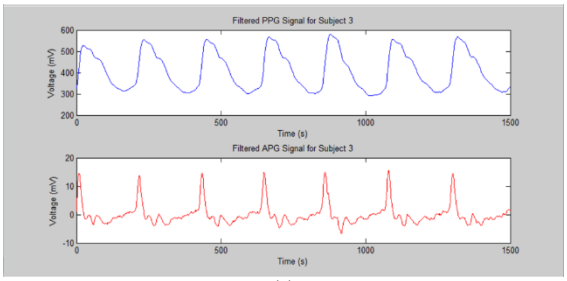


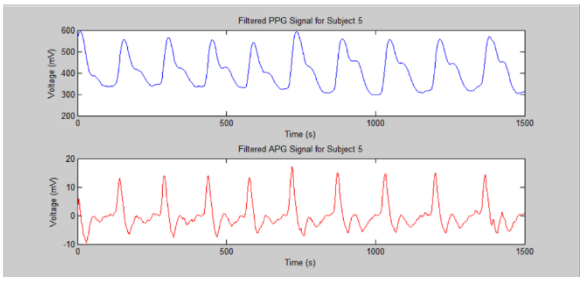
(c)

Figure 2(a): Filtered PPG and raw APG signals for Subject 3; (b) Filtered PPG and raw APG signals for Subject 5; (c) Filtered PPG and raw APG signals for Subject 7.

However, the PPG and APG signals still have additional method was applied by using a low pass second order Butterworth filter with normalized cutoff frequency of 0.25 Hz. However, this process was only used for APG signal since the PPG signal has been filtered by the high pass and low pass filters. The results of filtered PPG and APG signals of subject 3, 5 and 7 are shown as in Figure 3(a) until Figure 3(c) and it can be noticed that the PPG and APG signals are smooth waveforms after the noise was filtered.



(a)



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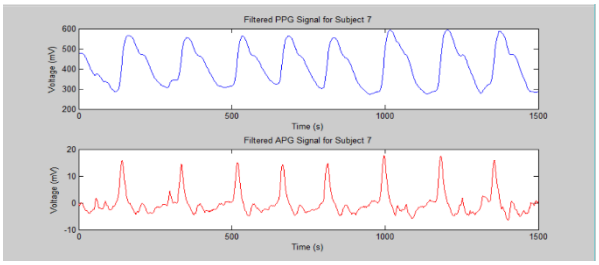


(c)

Figure 3(a): Filtered PPG and APG signals for Subject 3; (b) Filtered PPG and APG signals for Subject 5; (c) Filtered PPG and APG signals for Subject 7.

Next, the feature extraction process was applied in order to extract the features of the signals. The features that were extracted from the PPG signals data are systolic and diastolic parts, while the data that were extracted from APG signals are from point a up to the point c as shown as in Figure 4. The results after this process are shown as in Figure 5(a) until Figure 5(c).

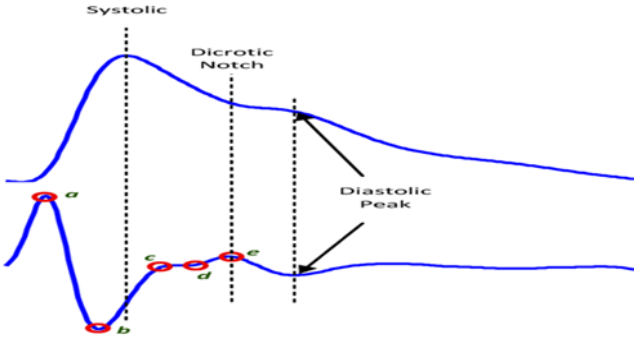
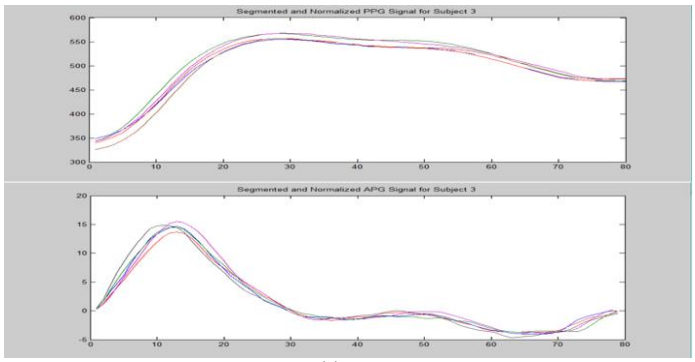
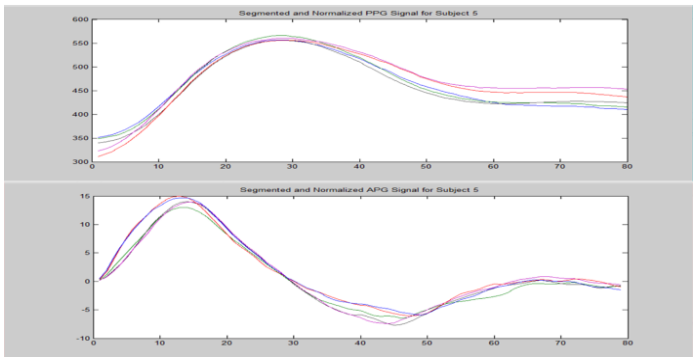


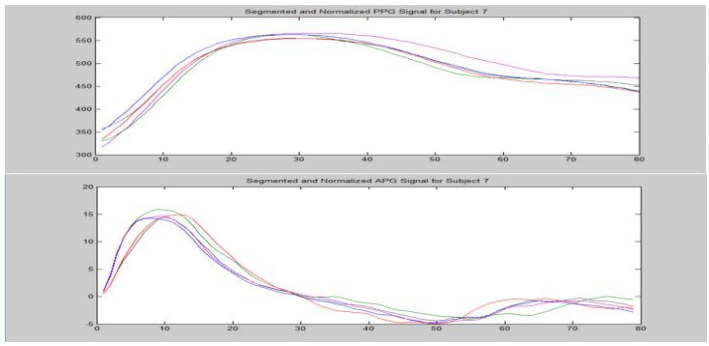
Figure 4: PPG and APG signals [6].



(a)



(b)



(c)

Figure 5(a): Segmented and normalized PPG and APG signals for Subject 3; (b): Segmented and normalized PPG and APG signals for Subject 5; (c): Segmented and normalized PPG and APG signals for Subject 7.

The last process applied is classification process and was applied by using WEKA software. There were two different datasets which undergo this process which are PPG and APG signal dataset. These two datasets were keyed-in into the software separately. The results obtained from four different classifiers are as shown in Table 1.

Table 1
Classification accuracies of PPG and APG signals from different classifiers

Classifier	PPG Classification Accuracy	APG Classification Accuracy
Bayes Network	84%	94%
Multilayer Perceptron (MLP)	84%	92%
Sequential Minimal Optimization (SMO)	90%	96%
K-Nearest Neighbours (IBk)	92%	94%

Based on the experimentation result, the classification accuracies percentage are different for every classifier for PPG and APG signals. Moreover, the percentage APG signal classification accuracies are higher than the PPG signal for

four different classifiers. This is because in PPG signal only systolic and diastolic peaks were being extracted while for APG signal point a up to point c were extracted from the features extraction process as shown in Figure 4. Therefore, APG signal will give higher identification rates as compared to the PPG signal.

Thus, from the experimentation results after the five processes were used to the PPG and APG signals, it shows that these waveforms have the potential to be used for biometric identification purposes. Even though these two bio-signals give different percentage results, the percentage of classification accuracies are still high.

V. CONCLUSION

This study is about the multimodal biometric system which uses PPG and APG signals in identifying identity of the individuals. Multimodal biometric system is a two level system of biometric and will better secure the identity of a person. The result obtained when four different classifiers show high classification rates for both PPG and APG signals. Therefore, by using multimodal biometric system it is anticipated that this system will be better in identifying identity of a person since it consist two levels of biometric system and it will protect individuals' identities as compared to unimodal biometric system.

ACKNOWLEDGMENT

We would like to acknowledge International Islamic University Malaysia for providing us the Research Initiative Grant Scheme to fund this research.

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