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Photoplethysmogram Based Biometric Recognition for Twins

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Abstract

This paper presents a photoplethysmogram (PPG) based biometric recognition technique for twins. PPG devices have been widely used due to its advantages such as non-invasive, low cost and small in size which makes it a convenient analytical tool. To the best of our knowledge, little has been set pertaining to biometric recognition for twins using PPG signal. A total of six subjects from three couple of twins were used for experimentation purposes. The signals were processed using a low pass filter to remove unwanted noise. Then, multiple cycle of PPG waveforms were extracted and later, Naive Bayes (NB) and Radial Basis Function (RBF) network classifiers are used to categorize the subjects using the discriminant features. Based on the experimentation results, classification accuracies of 97% and 94% were achieved when using Naive Bayes and RBF network respectively which suggests the capability of our proposed system to identify individuals regardless whether the persons is a twin or not. The outcome also provides complimentary mechanism to detect a person besides using the current existing methods.

Keywords: Naive Bayes, Photoplethysmogram (PPG), Radial Basis Function (RBF) Network, Systolic and Diastolic

1. Introduction

Identity theft is one of the fastest growing crimes in Malaysia. According to the report from The Malay Mail Online posted on November 25 2014, the Deputy Home Minister, Datuk Wan Junaidi Tuanku Jaafar told the Parliament that 565,157 MyKad were reported lost from 2010 to 2013. In another article, Sin Chew Daily urged the Home Ministry and The National Registration Department (NRD) to investigate where these lost cards have disappeared as MyKad is an important document which could be illegitimately abused. The Home Ministry did not deny these lost cards could have been misused by foreigners, particularly illegal foreign workers (1). In the black market, MyKad is extremely popular and it could be sold for RM5000 per card. This is because Mykad which has a microchip with biometric technology contains all of our personal information such as identity card number, date of birth, and other personal identification details.

Furthermore, in the United States identity theft in the state of Florida have been ranked as the number one complaint by consumers to the Federal Trade Commission for 15 years in a row. Figure 1 illustrates the identity theft complaints by year in Florida. Another case reported in Long Island, there were twin that used her twin sister's social security number to open up credit-card accounts and rack up more than $12,000 dollars (3). Thus, to overcome the aforementioned issues, one of the main strategies to combat identity crime is to implement biometric recognition.

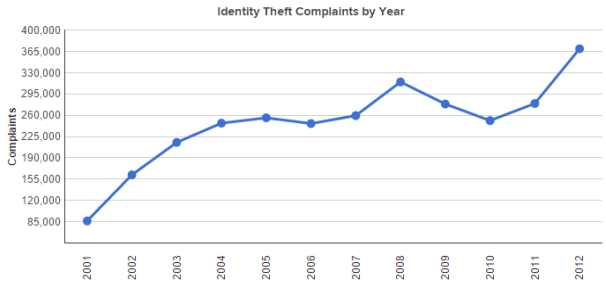

Figure 1. Identity Theft Complaints by Year in Florida (2).

Since a decade ago, biometric recognition is a trusted source to secure and safeguard personal data. It has been

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applied in financial, forensic, government agencies and etc. However, there are possibilities that people who have twin could create mischief in order to achieve their personal interest dishonestly. Therefore, it is very important to tackle this issue and if left untreated cause huge amount of monetary losses and to one extreme jeopardize a person's credential for the rest of life.

1.1 Motivation

Twins are unique human being which share same genetic. Sometime, they are hard to differentiate from each other. In some crime cases, which identical twins are involved, the investigator will have a hard time to determine which twin committed the crime. In addition, some twins may interchange their identity for their own benefit and may cause confusion to other people. Crimes involving twins cannot be taken lightly since it will give a negative impact and bad impression to the other twin which is not committed to the crime. Besides that, a twin's identity can be used to commit more serious crimes like credit card fraud. Twin can also manipulate their twin's identity to their own benefit. Many methods can be applied to differentiate twins such as DNA and face recognition. For DNA test, it takes times to process and get the result while for face recognition, since the twin looks alike it is hard to differentiate each of them.

In order to reduce this aforementioned issue, we need a technique to overcome this problem. Recently, PPG has been proposed as one of the biometric methodology. This technique has greater potential to assist the identification mechanism as it non-invasive, low cost and small in size which makes it a convenient analytical tool. This study also will be focusing on the effectiveness of the system in recognizing a person's identity and assessing the performance of the system as compared to the existing identification technique Thus, in this study, we will present a PPG based biometric recognition mechanism for twin identification.

1.2 Contributions

In this paper, we investigate the possibility of using PPG signals to identify twins. Based on the experimental outcomes, the contributions can be summarized as follows:

- Obtain high classification accuracy using the proposed technique.
- Achieve significant results as the related studies as the issue on the research area are under research.
- Verify that biometric is possible to be performed when dealing with twin.

1.3 Rest of the Paper

The remaining paper is organized as follows: Section 2 explained on the basic terminology of biometrics, twin and PPG followed by the literature review, Section 3 discusses the implemented methodology, and Section 4 describes the experimental procedures, results obtained and its performance comparison with other studies. Finally, Section 5 contains the conclusion of the study.

2. Related Works

This section consists of two main parts, which are basic terminology and literature review. These two concepts will be further explained in the next subsections.

2.1 Basic Terminology

This section will further describe three important terminologies used in this study which are twins, biometric system and PPG signals.

According to the Australian Bureau of Statistics, in 2013, a total of 4475 set of twins were born and represents 1.5% of all births. In addition, there are 75 sets of triplets and twins with higher order that represents 0.02% of all births (4). According to a recent report by the National Center for Health Statistics, birth rate in the United States of twin increased 76% from 68,339 to more than 137,000 births since 1980 to 2009 which consist of 18.9 to 33.3 per 1000 births as shown in Figure 2 (5).

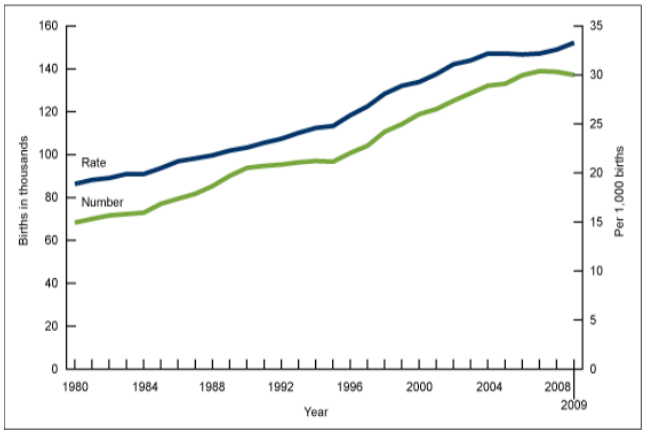

Figure 2. Number and rate of twin births in Unites States, 1980-2009 (5).

In another report, twins were born 1 in every 30 babies in United States, 1 in 50 at Japan, 1 in 250 at China, 1 in 76 at England and 1 in 49 at Norway, Denmark and Netherlands (5). A few treatments are available to obtain twins which are fertility drugs, in vitro fertilization (IVF) and intrauterine insemination (IUI) which increase the probabilities of having fraternal twins, where two are fertilized by two different sperm. We can get twin without treatment by several factors which are heredity, age, history of twins, number of pregnancies, race and body type.

Twins have two different types which are monozygotic or known as identical (MZ) and dizygotic that known as fraternal or non-identical (DZ). Identical twins occur when a single egg is fertilized by a single sperm to form one zygote (monozygotic) but the zygote then divides into two separate embryos and shares the same genetic information (6). While for fraternal twins, it occurs when two fertilized eggs are implanted in the uterine wall, at the same time, the mother releases two eggs and both become fertilized by two different sperms and it shares half of the genetic information. We can determine the zygosity as the same sex twin pairs based on the examination of the placenta and fetal membranes. For MZ, it can be categorized into four types as shown in Figure 3. In this study, we propose of identifying twins using biometric recognition. Thus, it is important to understand the concept of biometric.

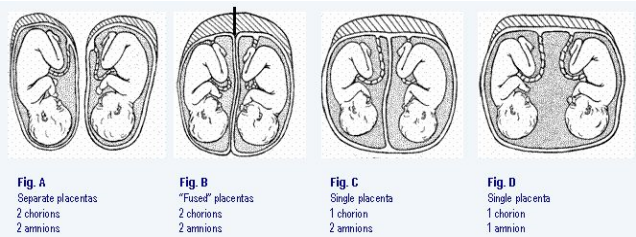

Figure 3. Types of monozygotic twins (4).

According to Jain et.al in (7), a pattern recognition system that operates by obtaining biometric data from an individual then, extracting features sets and comparing it against the template sets stored in the database is defined as a biometric system. Biometric system must meet the following characteristics as shown in Table 1.

Table 1. The characteristics of biometric recognition (7)

Requirement	Description
Universality	Every person must have these characteristic.
Distinctiveness	Any two persons with differences in their behavioural characteristic. Eg: A pair of identical twin with different palmprints.
Permanence	The character does not change over a long period of time.
Collectability	The characteristic can be measured quantitatively.

A system that used biometric for personal identification must consider some important issues such as performance, acceptability, and circumvention of the system. The effectiveness and efficiency of the systems are influenced by speed and accuracy that is considered one of the major factors of performance. In order for the system to be accepted by the public, it should be employ biometric modality which exist in every person. Moreover, the circumvention aspect is important is significant which indicates the strength of the system when dealing with various fraudulent methods and attack such as hacking and phishing.

Biometric system can be operated either in verification or identification mode. The verification mode or conducted as a one-to-one comparison system, determines who he claimed to be by capturing his biometric data and comparing the collected data against his own template set stored in the database system. This mode has been applied in border security system by comparing passport holder's fingerprints with the sample in the template to verify his identity. Figure 4 shows the procedure of biometric verification mode.

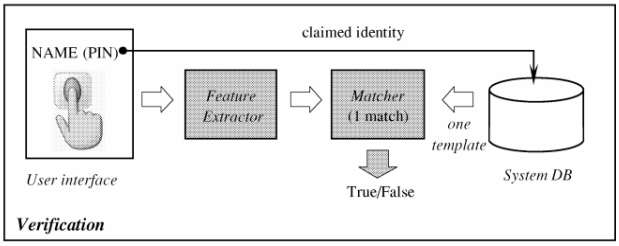

Figure 4. Block diagram of verification mode (7).

Meanwhile, identification mode or conducted as a one-to-many comparison system, recognizes a person without him having to claim his identity. This system identifies an individual by examining the patterns of all the users stored in the database for matching. This mode has been applied in forensic institutions. Figure 5 shows the procedure of biometric identification mode. The usage of biometric recognition like audio-visual, facial motion, 3D face and odour for the purpose of identification has been implemented. Each method of biometric recognition has its own characteristics and features that describe a person's identity. Recently, biomedical signal such as PPG signal has been implemented for biometric purposes. PPG waveform will be briefly discussed next.

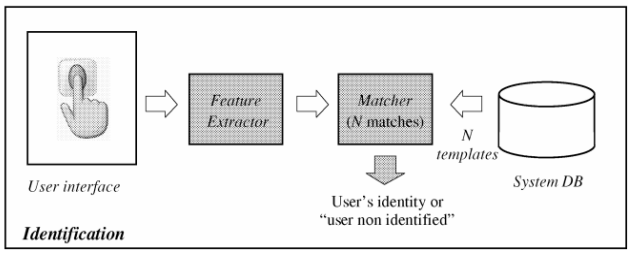

Figure 5. Block diagram of identification mode (7).

The application of PPG signals for biometric identification represents a novel approach in the area of secure authentication. PPG is used to evaluate the skin blood flow using infrared light. It is also used to measure oxygen saturation, blood pressure, cardiac output and assessing autonomic functions. PPG signal can be obtained using pulse oximeter that attached to the fingertip or earlobe.

2.2 Literature Review

In this section, we will discuss some techniques that can be used to detect twins. In this section, several techniques of detecting twins from few studies are discussed and compared.

Li et al. in (8) collected an audio-visual twin database for recognition systems during the Sixth Mojiang International Twins Festival. These methods contain three collection procedures which are using photo, facial motion video and audio recordings. Firstly, for photo method, they captured 2D face for each subject consisting one frontal image and two profile. Secondly, for motion video recording session, at least three times of 6 expressions were recorded which are smiling, anger, surprise, sadness, fear and disgust. Meanwhile for audio recording, 4 free talking were recorded and repeated 3 times with an interval of 3 seconds with continued for 30 seconds in average. Twins were will recognise based on 3 protocol specifications which are twins verification, twins identification and pairwise twins similarity. These methods are quite difficult because it takes too long for the processing time, too much procedures and this behavioural biometrics is not consistent with time and change as an individual grows older and some environmental factors.

Kong et al. in (9) conducted a study for personal verification based on identical twins' palmprints. In this study, they utilized the orientation fields of palmprints as unique features to represent low-resolution palmprints images and use angular distance to compare the unique features. Shorter angular distance indicates similarity between two palmprints images. A total of two set databases are needed to distinguish the general persons and identical twins palmprints. The images were collected from both right and left palms of the subject on two separate occasions which is two month apart. The subjects need to capture about 10 images for each of the both right and left palm on each occasion. A CCD camera-based palmprint scanner was used to collect the palmprint images. However, these methods have some intrinsic correlation which is not due to the side matching.

The finding of Roberts et al. in (10) presented the recognition of twins based on body odour similarity. There are three samples of odour taken which are from dizygotic (DZ) twin pairs, monozygotic (MZ) twin pairs, and duplicate odour samples from the same individual and compared the rates of exact matching for sniffers using a matching-to-sample experimental design. Individual odour will be influenced by some environmental factors such as effects of diet, disease, parasitic infection, social or reproductive status. Twins will wears a cotton pads in between 6-9 hours, put on the T-shirt before they went to bed and remove after rising and the sample were sealed in the plastic bag and kept at 4°C until -85°C approximately 14 hours later. These analyses were carried out using binomial tests in SPSS version 12. The result shows that the most sniffers match incorrectly because the poor discrimination and the real odour dissimilarity between twins were caused by environmental factors.

Priya in (11) proposed a proficient technique for distinguishing identical twins using facial features. In this

study, it is focuses on image retrieval by matching 2 of the basic features of identical twins which are facial and lip recognitions. For the facial part, the entire face was used to measure the accuracy of the characteristic between identical twin pairs. Meanwhile for the lip recognition, there are 2 ways of detection which are lip corner and lip highlight detections. After extracting the features of facial structures and lip region area, two classifier methods were used which are content-based image retrieval (CBIR) and text based information retrieval (TBIR) to identify the characteristic structures. The result shows that twins are easily identifiable. However, when the subject doing surgery on their face, then it quite difficult to identify the characteristic structures.

Vijayan et al. in (12) conducted a research on the performance of state of the art 3D face recognition algorithms on a large set of identical twins using the 3D Twins Expression Challenge ("3D TEC") dataset. There are four algorithms that were implemented in this study. First, Algorithm 1, using group of 38 spherical regions and merged the match evaluation to calculate the final performance. The face of each subject were approximately aligned using symmetry plane estimation approach and the photo was then aligned to a reference face using ICP (Iterative Closest Point). Second, Algorithm 2, there are 2 main steps which are intermediate facial representation used to mark on the local shape modifications of 3D facial surfaces in order to improve its distinctiveness and there have three types of intermediate facial maps which are shape index to describe shape attributes, extended Local Binary Pattern which were generated to represent a particular facial range image and Perceived Facial Images which stimulate the complex neuron response using a convolution of gradients in various orientation within a pre-defined circular neighbourhood. On the other hand, algorithm 2 which is Scale Invariant Feature Transform (SIFT) work as the matching process to obtain vigorous key points from the facial representations. In Algorithm 3, it transforms the 3D image to a surface normal representation then compare the images using the Euclidean distance approach. Familiar faces can be recognized by very low resolution images. Algorithm 4 which is UR3D algorithm contain 3 main steps, first is the 3D facial meshes which are connected to a common reference Annotated Face Model (AFM), second is the AFM that is deformed to fit the aligned data, and the last one is the 3D fitted mesh represented as a three-channel image using the global UV-parameterization of the AFM. This method can be applied directly to the image. However, the combination of features related to the facial resemblance of identical twins and the difference in facial expression makes for an extremely challenging problem.

Patil et al. in (13) proposed a SVD (Singular Value Decomposition)-EBP (Error Back Propagation) algorithm for iris pattern recognition. In this study, it contains two parts which are preprocessing technique and classification method using a Fued Forward Neural Network which the data were generated from the first part. The preprocessing technique consists of three steps which are image acquisition, iris segmentation and feature extraction. For image acquisition, the images of the iris were taken using special camera (digital optical sensor) that operates in the infrared spectrum of light. There are two segments in iris segmentation which are the detection of pupillary boundary and iris edge detection. The purpose of detecting the pupillary boundary is to finds the centre of the pupil and two radial coefficients. Meanwhile, iris edge detection finds the contour of the iris which traces a horizontal imaginary line that crosses the whole image passing through the centre of the pupil. The last step, which is feature extraction, reduces the problem of dimensionality by using SVD. The non-useful information was cropped out and only collects the desired number of Iris Basis rows and columns. For the classification method, different numbers of neurons are used to classify various dimensions for recognition. However, this technique is not recommended because the classification rates dropped abruptly to a very low value with larger class values.

As a summary, biometric recognition such as facial, audio-visual, palmprint and odour can be a medium to identifying twins. However, these aforementioned techniques are not recommended because some behavioural biometric is not consistent over time, for example, facial recognition, it change as an individual grows older or if they perform facial surgery which changes the original structure of their face. Other than that, the equipment used is quite expensive, for example digital optical sensor for iris recognition.

Nowadays, there is a more reliable alternative to overcome the aforementioned issue which is by using the PPG signal. This type of bio signal is more preferred because it is a low cost solution with low power consumption, easily available and simpler to use.

However, little has been said about the identity of twins using PPG based biometric recognition. Therefore, in this study, we will propose a technique to recognize twins based on PPG signal.

3. Methodology

For this study, there are four stages involved for PPG based biometric recognition system for twin. The four different stages are data acquisition, preprocessing, feature extraction and classification. Each of these stages will be explained in detail in the next sub-sections.

3.1 Signal Acquisition

In this study, we acquired the raw PPG signal which were collected from six individuals for 3 couple of twins which consist of four females and two males in a resting condition at the age between 25-21 years old.

3.2 Pre-processing

After we acquired the raw data, PPG signal will be processed in a low pass filter. This process will remove unwanted signal from the unfiltered signal. As a result, the signal will be smoothen and more clear from noise after applying the low pass filter.

3.3 Feature Extraction

This step consists of segmentation section. From the raw signal, we select one cycle of PPG waveform as shown in Figure. We find the starting and ending points of the PPG signal. However, it is difficult to evaluate and identify the phase changes (systolic and diastolic) of the waveform.

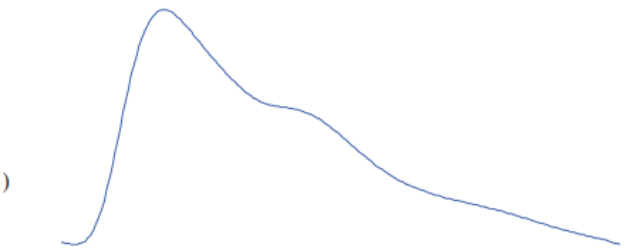

Figure 6. PPG waveform.

3.4 Classification

For the classification techniques, we will use two common classifiers which are Naive Bayes (NB) and Radial Basis Function Network (RBF Network). The description of this classifier will be briefly discussed in the next sub section.

3.4.1 Naive Bayes

Naive Bayes (NB) approach are applying Bayes' formula with the "naive" hypothesis of independence between every pair of features in a set of supervised learning as an over-simplified assumptions. Y as a class variable and a dependent feature vector x_1 through x_n, Bayes' theorem formulated as in Equation 1.

$$Y <- \arg\max_{yk} P(Y = y_k)\ \Pi_i\ P(X_i|Y = y_k) \quad (1)$$

In many real–time situation, NB classifiers have worked quite well, knowingly as document classification and spam filtering which only require a small amount of training data to evaluate the essential parameters.

NB classifiers and learners can be process in shorter period compared to more other classifier. The decoupling of the class conditional feature distributions means that each distribution can be individually predicted as a one dimensional distribution. This in turn benefits to improve the limitation from the curse of dimensionality (14).

3.4.2 Radial Basis Function Network

The main concept of Radial Basis Function (RBF) Networks comes from the function approximation theory. The RBF networks basically have three common nodes which are an input, a hidden with a non-linear RBF activation function and an output nodes with linear activation functions as shown in Figure 7.

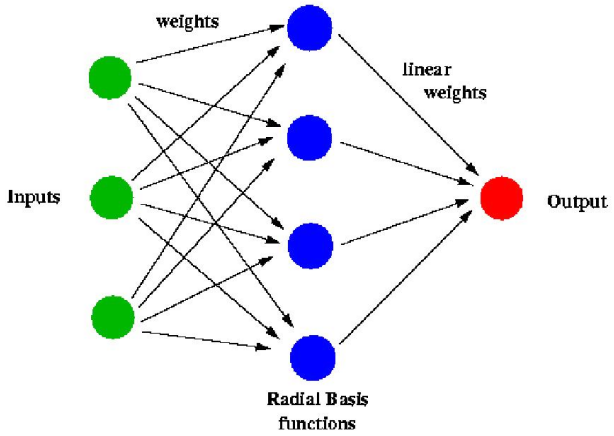

Figure 7. Structure of Radial Basis Function Network (15).

RBF Network also consist of network training. This training network was distributed into two different stages which are the weights from the input hidden nodes and the weight from the hidden to output nodes. Mathematically, this can be written as in Equation 2.

$$y(x) = \Sigma_{i=1} w_i h_i(x) \quad (2)$$

Where y(x) is the output, w_i is the vector of weights, and h_i is the vector of hidden units (15). After we acquired the raw data, PPG signal will be processed in a low pass filter. This process will remove unwanted signal from the unfiltered signal. As a result, the signal will be smoothen and more clear from noise after applying the low pass filter.

4. Experimentation and Results

In the signal acquisition stage, six PPG signals were taken from a twin. Next, these raw PPG signals are processed using low pass filter to remove the unwanted signal. The results of this step is shown in figures 8, 9, 10, 11, 12 and 13 that shows filtered PPG signals for Subject 1, Subject 2, Subject 3, Subject 4, Subject 5 and Subject 6.

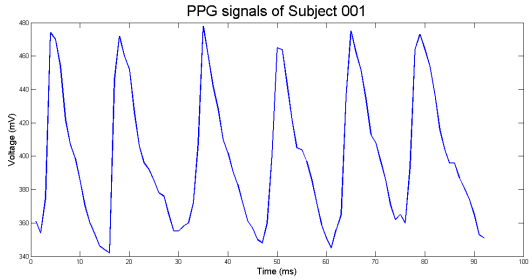

Figure 8. PPG signal for Subject 001.

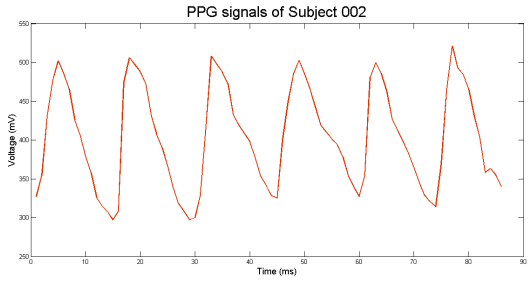

Figure 9. PPG signal for Subject 002.

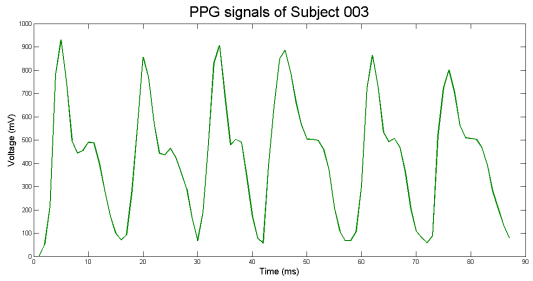

Figure 10. PPG signal for Subject 003.

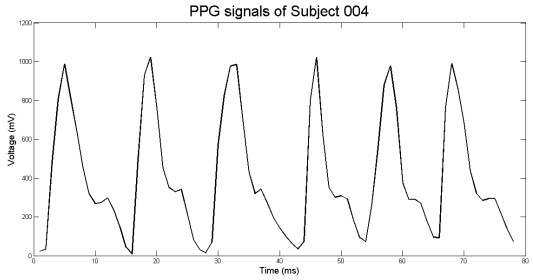

Figure 11. PPG signal for Subject 004.

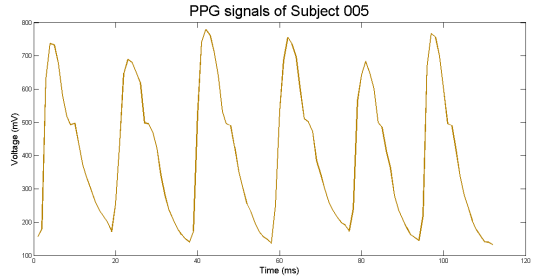

Figure 12. PPG signal for Subject 005.

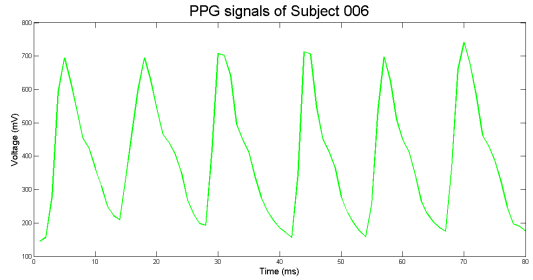

Figure 13. PPG signal for Subject 006.

Then, from the filtered signals, one cycle of PPG waveform is extracted which consists of systolic and diastolic regions that act as the biometric sample. Figures

14, 15, 16, 17, 18, and 19 show the PPG segmentation for each subject.

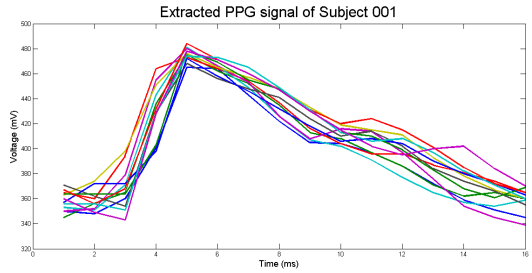

Figure 14. PPG segmentation for Subject 001.

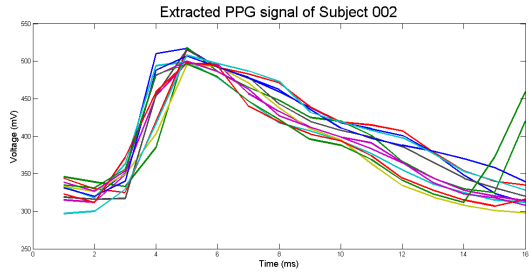

Figure 15. PPG segmentation for Subject 002.

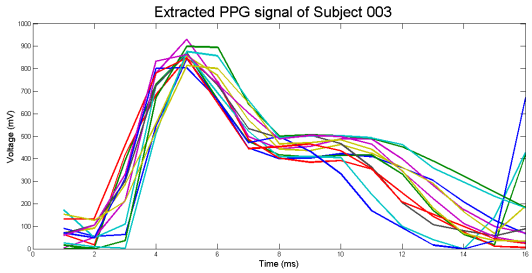

Figure 16. PPG segmentation for Subject 003.

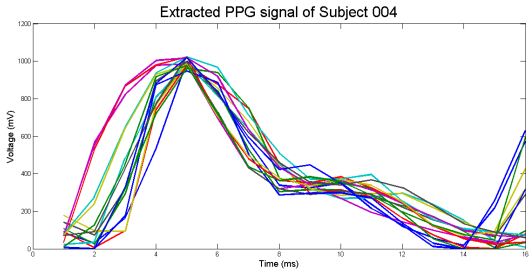

Figure 17. PPG segmentation for Subject 004.

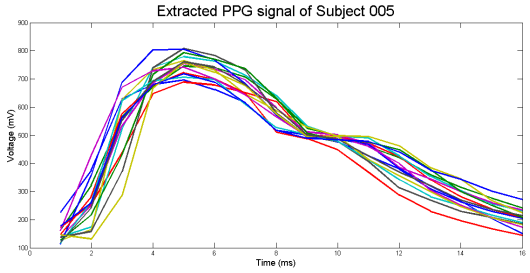

Figure 18. PPG segmentation for Subject 005.

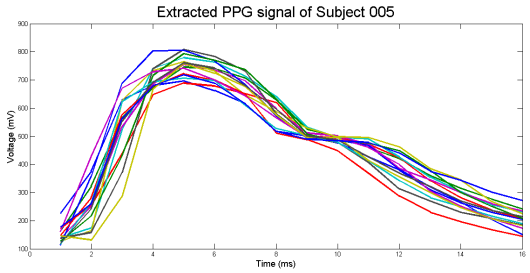

Figure 19. PPG segmentation for Subject 006.

From the observation of the study, each PPG signal shows a different pattern between one and another which suggests PPG biometric recognition is possible. For example, the systolic and diastolic regions of Subject 001 are different from Subject 003. Besides the pattern, each PPG signal also has different values of each of the segmentation which proves that every individual has a unique feature of the PPG. For instance, the peak value of the systolic region for Subject 005 is 743 whereas for Subject 001, the peak values of systolic peak is 464 and etc.

Then, the final stage of PPG based biometric system is classification. This step uses a data mining software called Weka. It is an application that consists of a collection of algorithms. As stated in the previous section, NB and RBF are used in the study. The results of the classification techniques are shown as in Table 2.

Table 2. Result comparison with other studies

Classifier	Accuracy %
NB	97
RBF	94

From the results, when using NB and RBF, the accuracy of 97% and 94% were achieved respectively. The outcome using NB gives better output because it has these advantages (14):

- A small amount of training dataset are needed to evaluate the required parameters.
- Compared to other classification approaches, NB and RBF processing time are faster.
- Every distribution can be independently evaluated as a one dimensional distribution.

Moreover, the high amplitude value of the systolic peak in male subjects as compared to female subjects contributes to a high identification rate. In other words, biometric features for males are more unique and discriminant. Therefore, as a proof of concept, it is proven that PPG based biometric recognition system for twins is feasible to be used which suggest high identification rate.

5. Conclusion

As a conclusion, the study achieved the research objectives. Generally, it can be said that PPG based biometric recognition system for twin is a possible and better way to recognize the identity of twins besides using other biometric modalities. All four stages have been completed and the processes of a PPG based biometric system have been understood. Based on the experimentation results, classification accuracies of 97% and 94% were achieved using Naive Bayes and Radial Basis Function Network respectively that suggest the capability of our proposed system to identify individuals. The outcome provides an alternative mechanism to detect a person for security purposes.

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